STANDARD AND EMERGENCY SHOP METHODS

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(*Frontispiece.*)

STANDARD AND EMERGENCY SHOP METHODS

BY

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PREFACE

Some years ago a well-known engineer who was not a shopman, asked the authors for a book that would give him a general idea of machine-shop operations and of the machines used. Since then others have expressed the same desire. This volume is intended to supply such information as will meet these and similar requests.

It begins with an outline of the various operations that machine shops are asked to do and shows the machines on which such work is usually performed. It is hoped that such general information not only meets the needs expressed by these engineers but also helps to prevent the perpetration of designs for machinery that are difficult or impossible to machine by ordinary methods. Such designs, some of which have been made in the engineering departments of well-known concerns, have not only greatly increased cost but have greatly delayed the war effort.

Following the standard methods of machining, which are usually to be preferred, the authors show how many of these operations can be, and have been, performed by entirely different methods largely to meet the war emergency. These examples show how experienced mechanics can adapt machines intended for quite different operations to work normally performed on other machine tools. In some cases these emergency methods have proved more efficient than those formerly considered as standard.

It is hoped that this combination of standard and emergency shop methods may add to the shop knowledge of mechanics in many lines of work. The methods should prove especially valuable to men in shops with limited machine equipment and so enable them to handle work they would otherwise have felt it necessary to send out to other shops.

THE AUTHORS.

NEW YORK,
June, 1945.

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those with limited experience are not aware that work can be machined on other than regular, or standard, equipment or by methods that seem unconventional

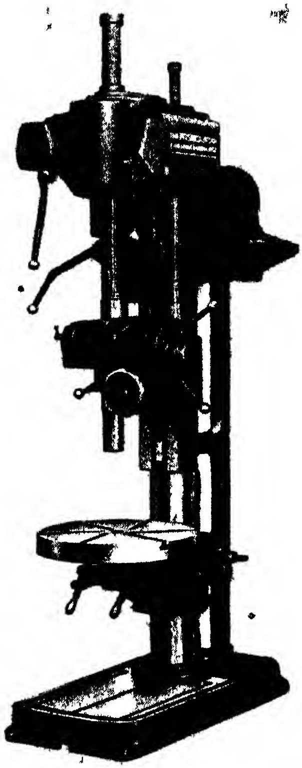


FIG. 1

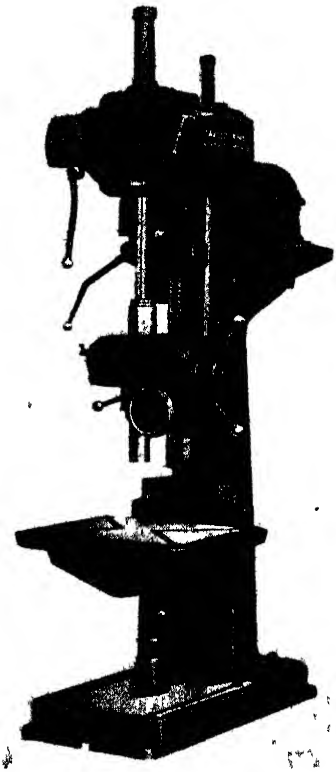


FIG. 2.

FIGS. 1 and 2.—Upright or vertical drilling machines.

These Fosdick machines show both the round-column and the box-column type. The table of the former is also round and can be turned in its supporting arm and clamped in any position. Both arm and table can be swung out of the way and tall work supported on the base of the machine. The rack by which the table is raised and lowered moves around the column with the arm. This type is convenient in job-shop work.

The box-column machine is more of a manufacturing type than the round-column type and is selected for the particular kind of work to be done. It is more rigid and can handle heavier work both because of the box column and because of the supporting screw under the table.

Men with wide experience in jobbing shops and in shops devoted to the maintenance of equipment on railroads, sugar plantations, the oil fields and other industries know that almost any repair job can be handled if a drill press, an engine lathe, and a planer or shaper are available. In fact almost unbelievable

jobs can be done on the engine lathe alone from drilling to shaping; for keyways have been cut with a tool held in the tool post of an engine lathe and moved in and out of the bore by hand.

It is well to remember that the engine lathe is still the basic machine tool in the shop. With a good engine lathe and a few attachments, an experienced man can do almost any type of

FIG. 3.—Bench drilling machines.

Small vertical drilling machines mounted on bases that rest on benches or on supports of similar height. They are usually mounted singly, but it is frequently convenient to mount two or more on a single support. As shown, these Delta drills are mounted in pairs. The work is moved from one spindle to the other to perform a different operation at each station. In some cases four or six drills are mounted in this way. In such cases they are usually run by more than one operator—the work passing from one to the other. Mounted in this way they are known as "gang" drills and should not be confused with multiple-drilling machines, which have a number of drill spindles driven from one central source of power.

machine work within its capacity. This includes drilling, boring, facing, grinding, milling, turning, and threading. It even includes shaping and broaching. Although most of these are only emergency operations, they are possible if it is necessary to get some vital piece of equipment back into operation.

It is felt that, by illustrating a number of the machine tools commonly used or now found in many shops, the reader will acquire a wider knowledge of the shop than if only a few were

presented. Those shown, however, do not begin to cover all the machines available for the various kinds of work.

In addition to illustrating standard machine tools, it seems advisable to show some of the ways in which they are used. This will give a much better idea of their possibilities and of the

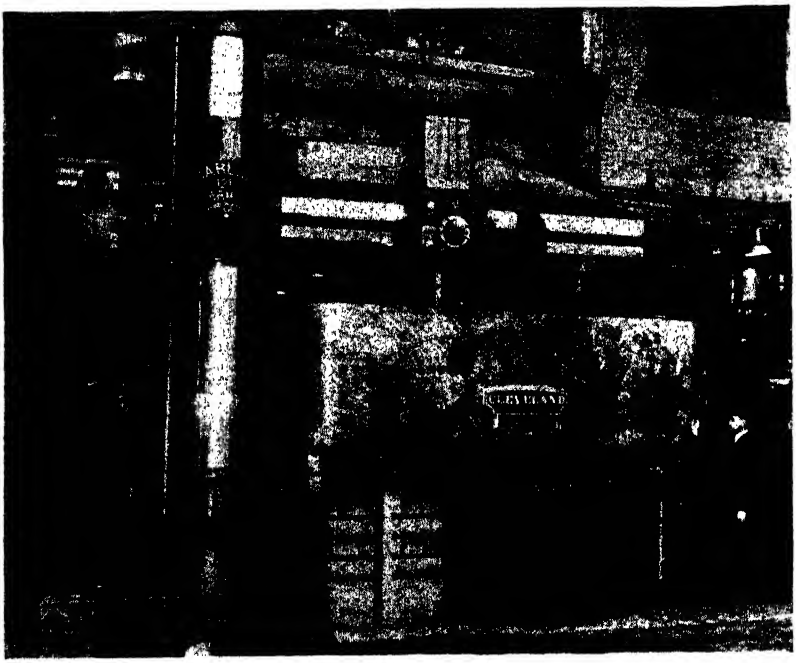


Fig. 4.—Radial drilling machine.

This shows a very large Carlton radial with an arm 12 ft. long mounted on a 26-in. column. It is at work on a casting approximately 12 ft. square. This type of drilling machine is very useful on large work as the drilling spindle can be moved into any position within its range. For average shop use, arms 4 to 8 ft. long are most useful but even 3-ft. arms have their place. These are very versatile machines and are used in the building of all kinds of large machinery.

For light drilling, some make a joint in the swinging arm and secure desired distance from the column by using this 'elbow' instead of sliding the head along the rigid arm.

work they can do. It should also assist in the selection of the machines best suited for a specific job.

Although the machines shown are believed to be fairly typical of those found in various plants, it should be remembered that similar work can be done on other makes of machine of the same type. Previous experience and the machines available in shops of various kinds will influence any user in picking equipment for his own purposes.

Standard Machine Tools.—As standard machine tools constitute such a large proportion of the machines used in shops of all kinds, it is necessary to become familiar with them and the ways in which they are used before one can adapt them to emergency uses. For this reason the leading types of standard machines are illustrated and their uses described at some length in the pages that follow.

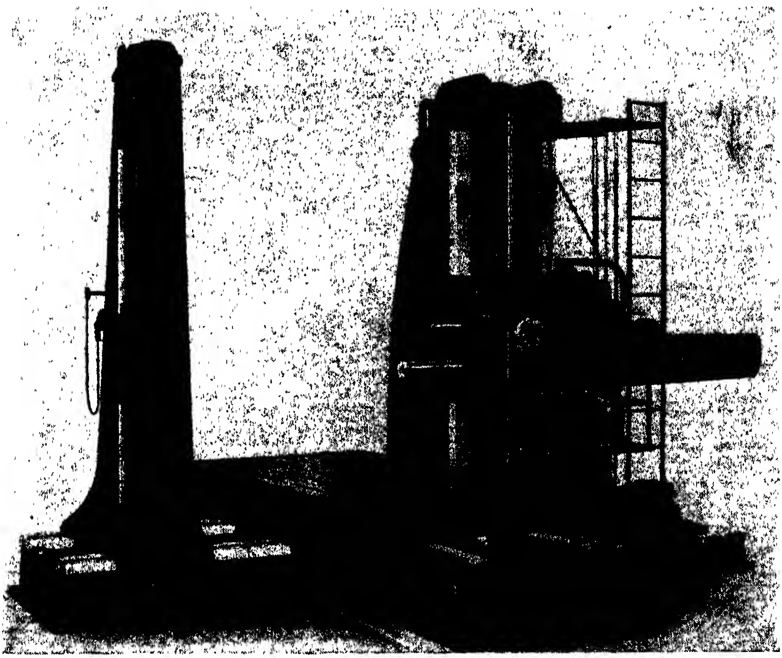


Fig. 5.—Giddings and Lewis horizontal boring machine.

This design has an auxiliary spindle for high-speed drilling above the large main spindle. The spindle feeds the boring tools into the work that is stationary on the table. The work remains stationary except as it is moved to bring new hole locations into line with the spindle. These machines are also used in many milling operations by mounting milling cutters on the spindle.

Not all these illustrations show the latest machines built by the different makers, but they do give a general idea of the appearance and, more particularly, of the type or class of machine to which they belong. There are of course other makes of machines of the same types doing similar work.

Before illustrating or describing the individual machine tools, it seems best to outline the different machining operations so that the uses of machine tools and the need for them can be

better appreciated. Following this is a brief description of the machines of various kinds and illustrations of some of them. With this information as a background, even those not already familiar with modern shop tools and practices will be in a position to form a fair idea of the machines likely to be best adapted to the work under consideration.

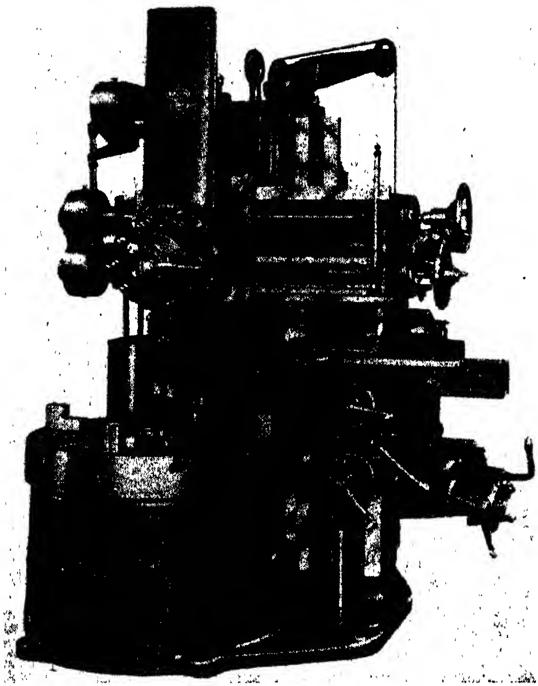


FIG. 6.—Bullard vertical turret lathe.

It is a vertical boring mill with a side head. This makes it into a lathe so far as its capacity for turning and boring is concerned. The length of work is limited by the height of the cross rail carrying the ram and turret.

Machining Operations.—Brief outlines of the basic machining operations seem a logical introduction to more detailed descriptions of the machines themselves. These are not intended to be strictly technical but rather general so as to be perfectly clear to those who have no actual shop training. Machines for these operations are shown in Figs. 1 to 45.

Drilling.—Drilling is the making of holes in solid metal. Although the twist drill is used almost exclusively for this work,

flat drills are frequently found. In the drilling of holes up to 3 in. or more in diameter, the flat cutter in the end of a bar is often used in the oil country and elsewhere, such as for boring the holes in cannon forgings. The helical flutes or spaces between the lands of twist drills make it easier for chips to escape. In some work it is important to have these flutes polished so that

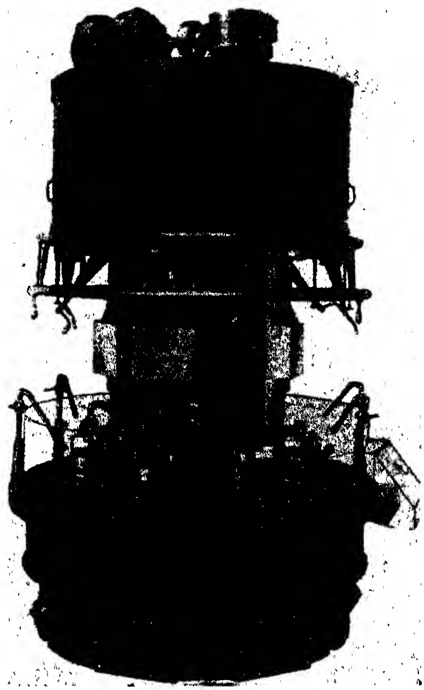


FIG. 7.—Bullard Multaumatic or automatic boring mill.

It is really five automatic vertical boring mills in one. The sixth position is for loading and unloading the work. The tool heads are automatically controlled. It is designed solely for mass-production work.

the chips will slide out easily. The angle of the helix is also important in drilling some materials.

Boring.—Boring is the enlarging of holes already made by drilling or provided in a casting or forging. This is done with a single-point tool in either a lathe or a boring mill by revolving the work or by rotating the tool inside the stationary work. Multicutter boring bars are also used. Boring bars may be used in the machine, or they may be portable and used on large

work resting on the floor. Supports are provided for the bar at each end, and power is supplied by electric or gasoline motor or by belt.

Turning.—Turning is the removal of metal from the outside of a bar or shaft. The bar usually turns while the tool remains stationary. As this is not always the case, examples will be shown where the bar is stationary and the tool revolves around it. These are called "sweep" tools because they sweep around the work. The lathe, the best known turning machine, is made

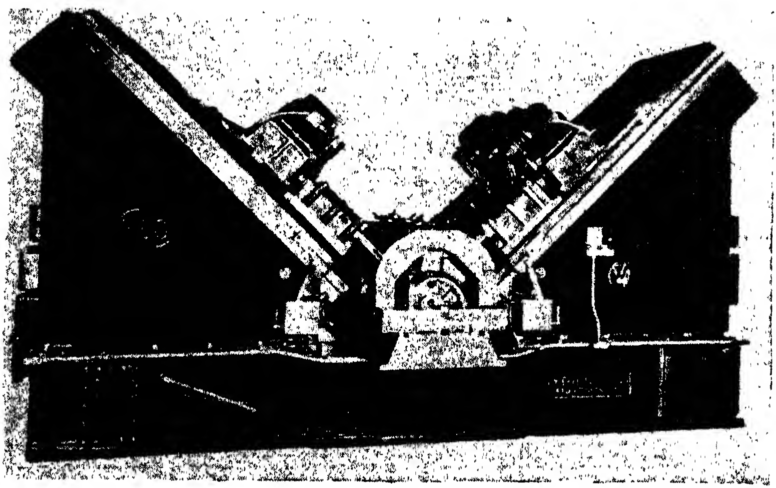


Fig. 8.—Special Ex-Cell-O boring machine for machining the cylinder bores of V-8 cylinder blocks.

There are eight spindles each carrying a boring tool that is fed into the cylinder as the heads move down the inclined ways. Single-point boring tools are used and great accuracy is obtained.

in a number of different forms. But in all of them the work turns against stationary tools.

Surfacing.—Although, in one sense, all kinds of machining operations can be considered as surfacing, the term is usually applied to producing plane or flat surfaces by traversing the work or the tool as with the planer, shaper, slotter, miller, or surface grinder. Flat surfaces are also produced by feeding a tool across work held in a lathe or boring mill. This type of surfacing is designated as "facing," whether the flat surface is produced on the end of a piece or on a collar or flange. Flat surfaces are also produced by broaching, as will be seen later, and by

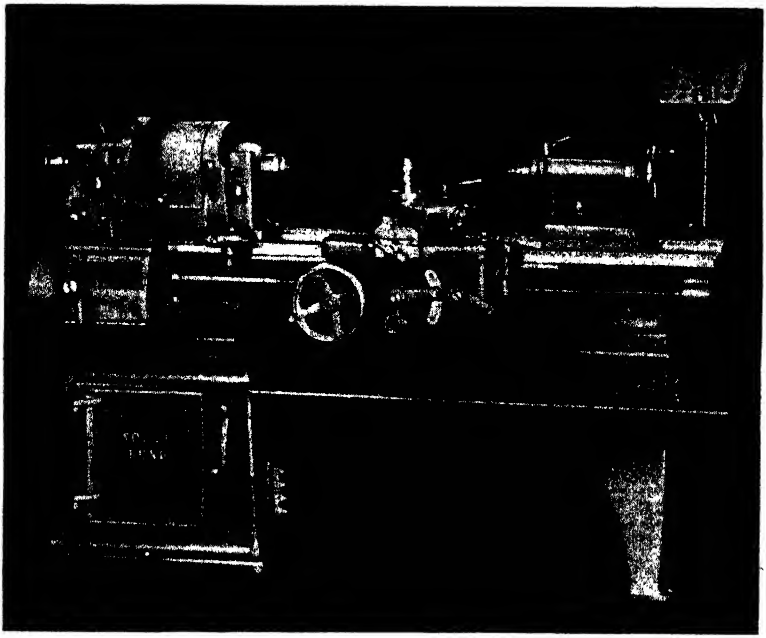


FIG. 9.—Engine lathe.

All regular turning machines are lathes of some sort, although work can be turned in drilling machines and in boring machines as will be shown. A popular small engine lathe is the South Bend shown here with the motor mounted in a base under the headstock. The bed is supported on the base and by a divided-leg casting that holds the chip pan between its two sections. This is shown with draw-in collets for toolroom work.

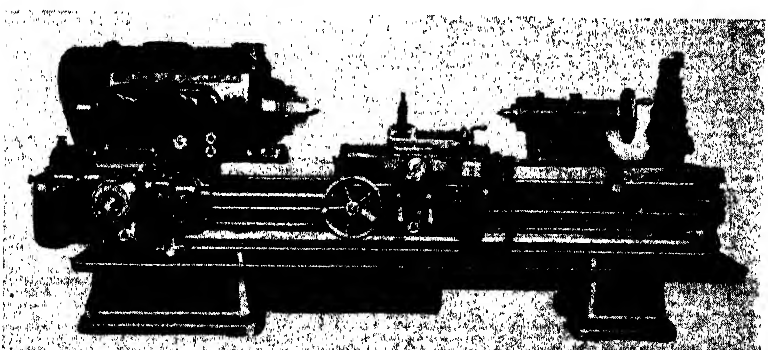


FIG. 10.—A Lodge and Shipley 22-in. engine lathe made by one of the oldest builders.

The motor is at the rear of the base under the headstock. The geared head has 24 speeds, from 9 to 500 r.p.m. The gearbox gives a choice of 55 threads and feeds. It has the standard spindle nose, automatic lubrication, and many other conveniences.

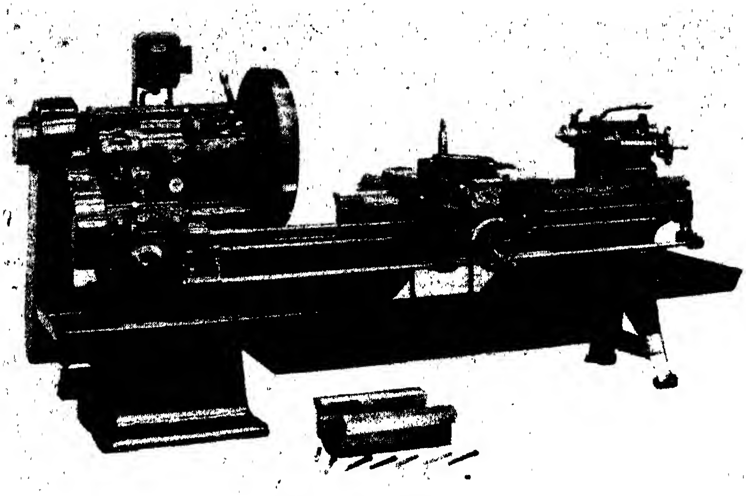


FIG. 11.—Gap-bed engine lathe.

This type of lathe is made to permit larger work to be handled on the face plate than will swing over the bed. Gap lathes are made in two ways. The smaller lathe has a separate block that forms the bed next to the headstock for regular work but that is removed to increase the swing.

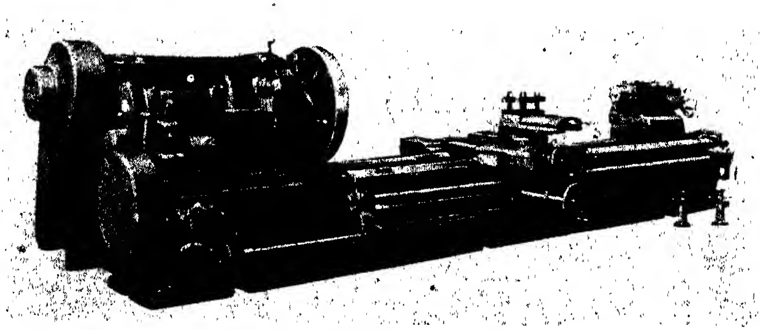


FIG. 12.—Gap-bed engine lathe.

Another gap lathe that has a base on which the lathe bed proper moves to form a gap between it and the headstock. It will be seen that power to move the carriage comes from the feed rod that is below the gap. The gearing from this drives the lead screw used in cutting threads. Both of these lathes (Figs. 11 and 12) are made by the R. K. LeBlond Machine Tool Company.

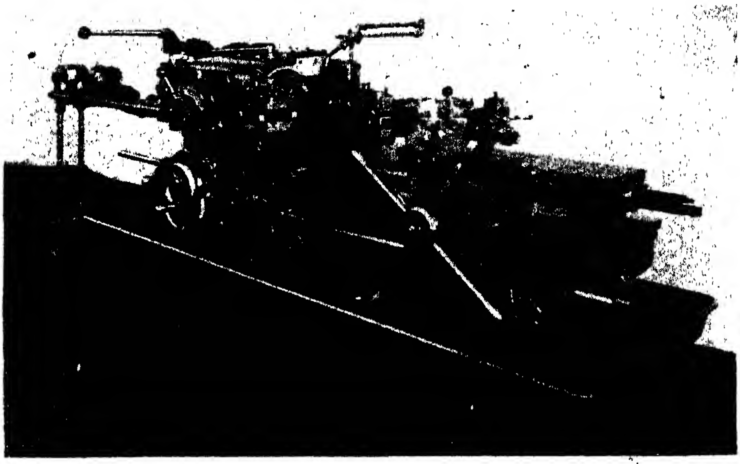


FIG. 13.—Ram-type Jones and Lamson turret lathe with a cross slide carrying cutting-off and forming tools.

This type of machine is called a capstan lathe by the British. The turret in the ram carries a variety of tools so that several operations can be performed at one setting of the work.

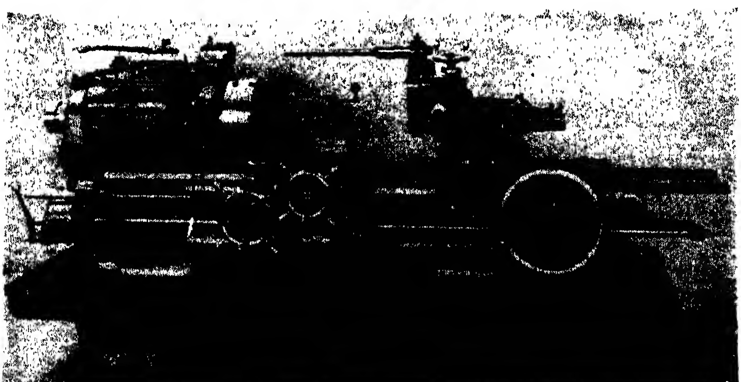


FIG. 14.—Saddle-type Warner and Swasey turret lathe that also has a cross slide.

The difference between the ram and the saddle types is in the way the turret is supported. In the ram type the turret slides in a subbase mounted on the bed of the lathe. In the saddle type the supporting saddle moves along the bed of the lathe.

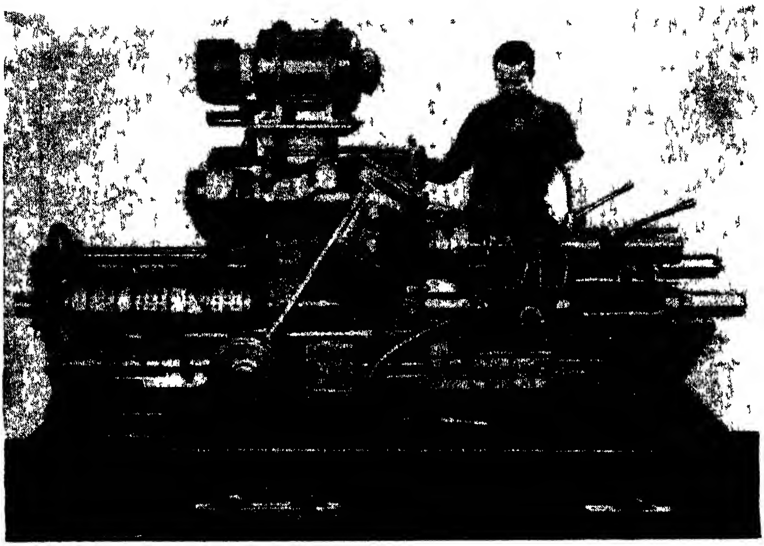


FIG. 15.—A semi-automatic Fay lathe in which the tool movements are controlled by the cams shown at the left end of the lathe.

Machines of this type are very useful where large quantities of the same piece are required. This type of automatic lathe is designed for machining individual pieces such as the cylinder barrels of airplane engines.

FIG. 16.—A Gridley full-automatic machine designed to work from long bars.

It feeds the bars in automatically as needed after a piece has been machined and cut off. This machine works on four bars at the same time

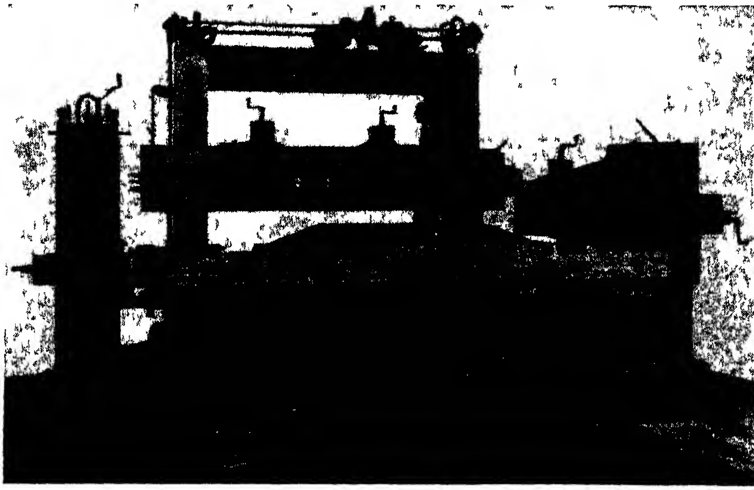


FIG. 17.—A large standard Cincinnati double-housing planer with two extra tool heads, one on each side.

These plane the ends of a long piece that will not go between the housings of the planer the regular tool heads on the cross rail are not used in this operation

FIG. 18.—Planing a number of frames or punch-press beds at one setting. This is known as "string" planing. This is a standard double-housing planer.

lapping where extreme accuracy is required. This is a form of grinding where an abrasive powder or paste is used between the surface to be lapped and a lapping plate.

Planing.—Planing generally refers to the removal of metal from flat surfaces. The work is held on a table which passes under the tool or tools. Planers are made in many different types and for many different purposes. In one, known as the "rotary planer," the cutting tools revolve as the work is fed

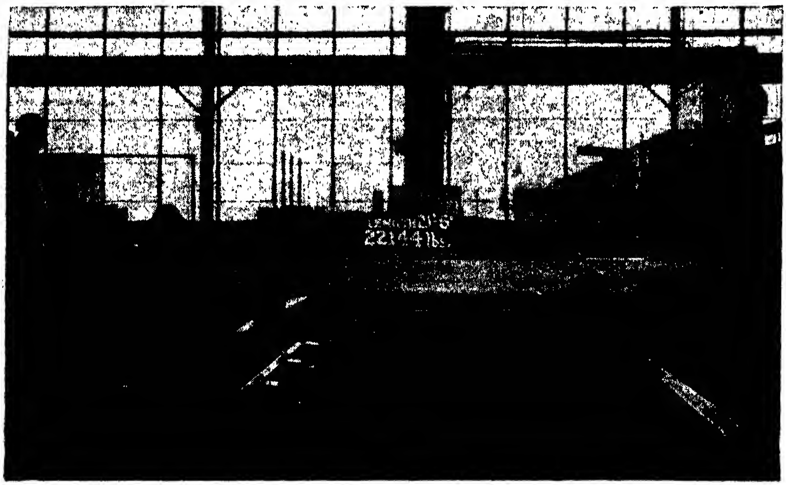


FIG. 19.—An open-side Gray planer machining the end of a very long and heavy piece of work.

The outer end of the work is supported by a heavy I beam planed on top to act as a guide. The tie rod keeps the sliding piece under the table at the proper distance from the bed of the planer so that it cannot slide off the supporting rail.

past them. This is in reality a milling machine rather than a planer.

Shaping.—This is another operation for producing flat surfaces. Here the work is held stationary while the cutting tool moves over it. In the regular type of shaper the ram carrying the tool is horizontal; in some cases the ram moves vertically. These are really slotters instead of shapers.

Slotting.—This operation is similar to shaping except that the ram carrying the tool moves vertically. It is more convenient in some classes of work than the horizontal machine. Small machines of this type are now used largely in toolrooms, and the larger machines are found in railroad and similar repair shops.

Milling.—Although milling is, in most cases, another operation for producing flat surfaces, milling machines are made for a large variety of work. Generally the work passes rotating cutters, as in the case of the rotary planer previously mentioned. There are also millers in which the head cutter rotates

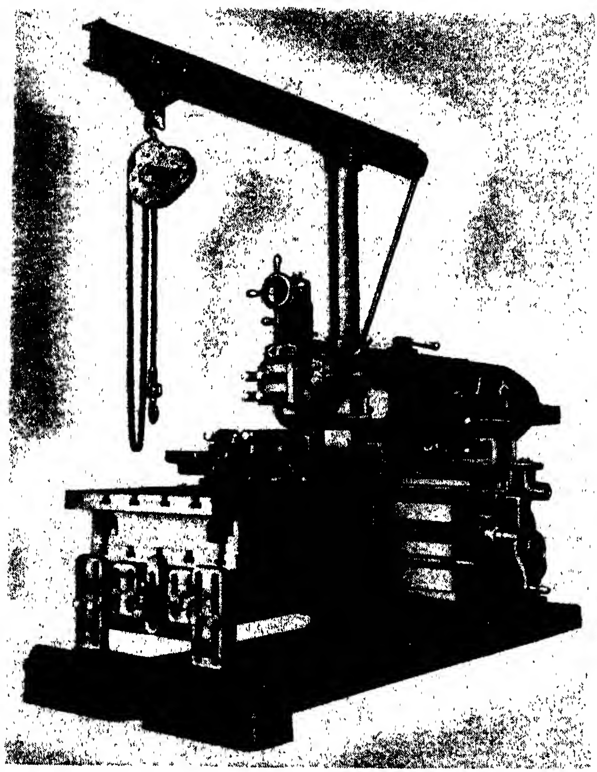


FIG. 20.—Shaper.

Shapers may be called short stroke planers in which the tool moves *over* the work instead of the work moving *under* the tool. The Ohio Dreadnaught shaper shown is one of the largest built. It is largely for railroad-shop use. The table is unusually large and heavy. The hoist shown indicates the size of the work for which it is designed.

Shapers are made in many sizes from those that are mounted on a bench and that have a stroke—or tool travel—of 6 or 7 in. to those like the one shown here that probably has a 36-in. travel. Shapers are seldom used in production work but are very convenient for job- or contract-shop use.

past the work. These are known as "planetary millers" and have many uses, one of which is in the cutting of threads either inside or outside a piece of work.

Gear Cutting.—Gear cutting involves several types of machines that resemble both the milling machine and the shaper. Gears

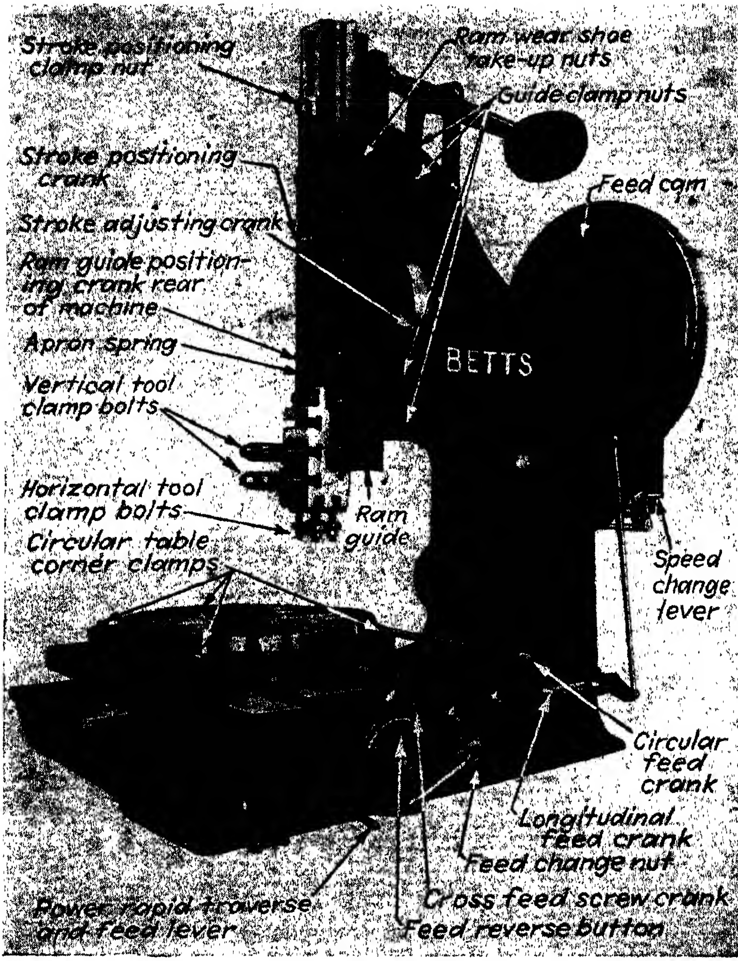


Fig. 21.—A large Betts slotter.

The smaller machines of this type are called "vertical shapers." The resemblance to a shaper is easily seen as the ram carrying the tool moves vertically instead of horizontally. These machines are very convenient on short-stroke work. The work is held on a table that can be fed toward the column across the bed or that can be rotated when the work needs to be machined on curved surfaces.

can be cut on plain milling machines by using a suitable indexing mechanism. They can also be cut on shapers by using similar devices. But for commercial gear cutting there are many special types of machines, each having its place in the production of gears. The various types will be shown so that their differences can be noted. Details as to their use will be given in the proper place.

FIG. 22.—A Nichols hand-type milling machine.

This is very useful on small work. The head carrying the cutter moves up and down on the slide while the table carrying the work moves under the cutter. Both movements are operated by the hand levers shown. Although a hand-operated machine, there are many operations that can be done very economically on these machines.

Grinding.—Grinding machines are made in many forms. In each the grinding or abrasive wheel takes the place of a metal cutting tool. These machines are used for both flat and round work, for external and internal grinding, and for many special purposes. Although generally used for finishing operations, some grinding machines now work from a rough forging or casting and remove large amounts of metal.

Honing and Lapping.—Both of these processes use abrasives and so may be classed as forms of grinding. Honing uses an abrasive head of the size of the hole to be ground and combines rotary and reciprocating motions. The amount of metal removed is small, rarely over 0.020 in. and frequently but 0.002 in. or less.

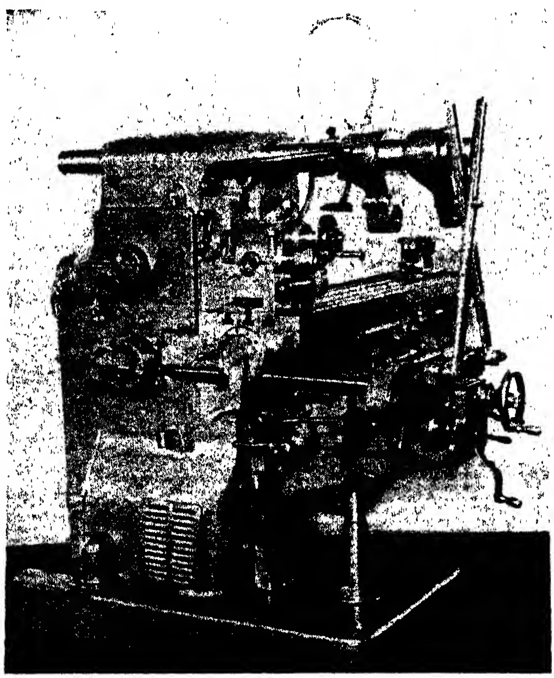


FIG. 23.—A Brown and Sharpe universal milling machine.

This is known as a knee-type machine as the work is held on a knee that moves vertically on the column of the machine. The plain miller is similar to this except that the table does not swivel as in this case.

Lapping, a process for finishing either flat or round surfaces by means of a fine abrasive, is frequently done by hand. One form of lapping machine is shown in Fig. 45.

Broaching.—Although broaching is, in most cases, a method of finishing work with a reciprocating tool, rotating broaches are sometimes used. It is generally confined to the finishing of holes of any desired shape, but it is also used for outside surfaces as well. The broach is a bar of steel having a series of teeth,

each successive tooth removing a small amount of metal as the broach is forced through or past the work, or as the work is forced through or over the broach.

Hubbing.—Hubbing is a process whereby a metal form is forced into a block of metal to be used as a die or mold for making parts of the same shape. It is done hot or cold in some cases. It should not be confused with hobbing, which is a milling operation used in cutting gear teeth and splines.

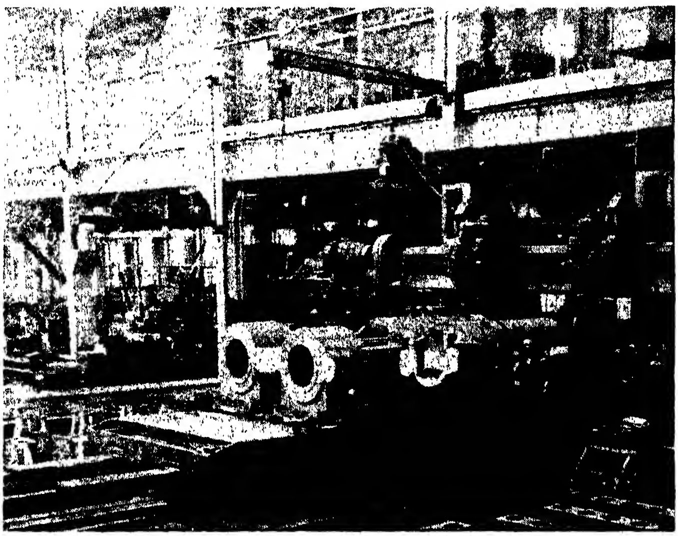


FIG. 24. A Sellers planer-type milling machine at work on large engine beds. The general construction resembles the planer but milling cutters are used instead of the regular planer tools.

Uses of Machine Tools.—Although the ways in which machine tools are used vary widely among different shops, depending largely on the equipment available and the experience of the men, it is well to know the normal or general applications of the different machines. As already indicated, the kinds and the uses of these machines vary, but the following outlines may be of service to those not thoroughly familiar with all of them.

Drilling Machines.—There is a very wide range of drilling machines, from the small, sensitive bench machines used by watch and instrument makers in drilling holes but 0.003 to

0.004 in. in diameter, or about the size of an average hair, up to those that drill holes 3 in. or more in solid metal. They also vary greatly in appearance as can be seen from the different types in the accompanying illustrations. Some of the uses will be noted in later chapters. Under some conditions drilling

FIG. 25.—Vertical Newton milling machine with rotary table. Here the work is fed under the milling cutters as the table revolves.

machines are used for turning and even milling, as will be shown.

Engine Lathes.—Generally speaking, all turning is done on lathes of some kind, from the small bench machine to the huge lathe for turning crank shafts for large vessels or the guns used by battleships or land defenses. The engine lathe is the backbone of all turning, whether the work is held between centers, in a chuck, or bolted to the faceplate. In most cases the work

is done with a single tool which is fed along the work. The engine lathe can, however, be used for drilling, milling, grinding, honing, and lapping, and even for slotting in an emergency.

Turret Lathes.—These are outgrowths of the engine lathe in which the tailstock and its center are replaced by a turret carrying a number of cutting tools of various kinds. The work

FIG. 26.—Ingersoll drum-type milling machine developed for use in the automobile industry.

The work is held on a drum that revolves between two sets of milling cutters as shown. There are two other milling heads on the other side of the machine so that the cut can be divided among a number of milling cutters.

is held in a chuck on the lathe spindle. The turret lathe does drilling, boring, turning, facing, form turning, and tapping and is a timesaver when the quantity of similar pieces warrants setting up the lathe and the expense of the necessary tooling. With modern standardized tooling now supplied by turret lathe builders, it is frequently economical to set up the lathe for as few as 10 or 12 duplicate pieces. The more that can be made

with the same setup the more economical it is, up to a point where tool breakdown limits production. This should be decided by practical experience.

Planers.—For obtaining flat or plane surfaces on almost any kind of work the planer is one of the logical machines, especially where the quantity to be made is small. It can also do slotting and dovetailing in a line parallel to the table travel. Like the

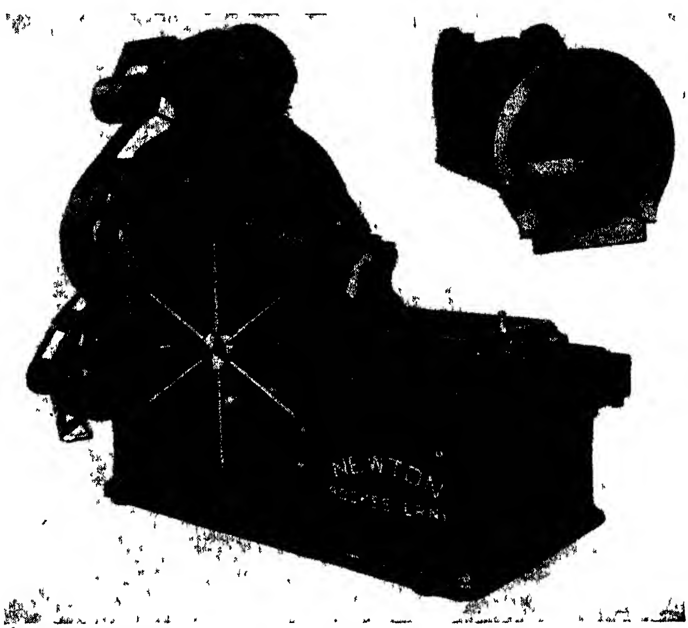


FIG. 27.—Newton planetary-type milling machine used in the automobile and similar industries.

Here the head carrying the milling cutters revolves and carries the cutters around the work. In this case the right-hand cutter faces the work while the left-hand cutter mills the inside of the end of the piece shown. This type has the advantage that the cutter for facing the work need be only large enough to cover the face of the flange as it revolves.

engine lathe, it is particularly economical in machining a small number of pieces. The single-point tool that is used is similar to that in the engine lathe and is easily adapted to small-lot work. Modern practice uses a number of cutting tools on the planer instead of the single tool as originally planned, thus greatly increasing the productivity of the machine. Multiple tools, however, add to the first cost of the operation and are justified only where the quantity warrants this expenditure. In

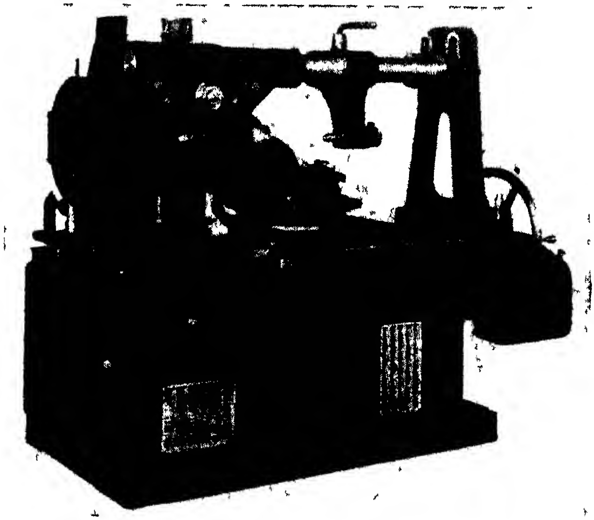


FIG. 28.—Barber-Colman gear-hobbing machine.

The hob- or gear-cutting tool is shown in a horizontal position below the centers that support the gear blank while it is being cut. This is a continuous process and is largely used in gear production. Few gears are now cut by the old milling process.

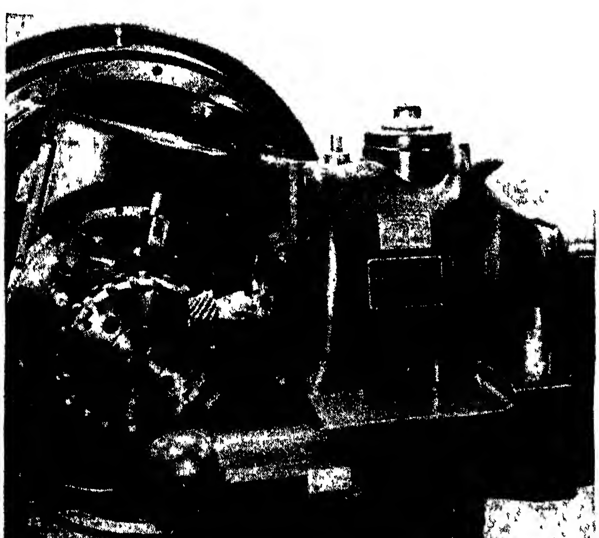


FIG. 29.—Gleason hypoid gear cutter at work.

Although this was a development for the automobile industry, gears of this type are now being used in many other types of machinery. The cutting is done by the special face-milling cutter and the gear blank also turns at the same time to secure the desired shape of the teeth.

some cases it enables the cost of planing to compare with that of the milling machine, which has become a rival in producing similar surfaces in quantity.

Planers are used with many ingenious setups to produce work at low cost. With multiple tooling, as will be seen, and four cutting heads, they can produce work at much lower cost

FIG. 30.—Gear shaving.

This is a fairly recent method of finishing the surfaces of gear teeth. The finishing is done by a special tool resembling a gear as in Fig. 30. This tool has five serrations on each of its teeth. When these run in contact with the gear to be finished, they cut five shavings from the surface and finish the teeth to the desired form and surface. This is part of a large machine built by the National Broach and Machine Company to shave gears up to 96 in. in diameter. The two cone points and the indicator at the right are for checking the accuracy of the gear teeth, as seen in Fig. 31.

than was formerly thought possible. Planers are sometimes fitted with special heads for milling and for grinding, and milling and grinding machines resembling planers in general appearance are also made.

Shapers.—The shaper is another single-point surfacing machine that can be used on a large variety of work. In both the lathe and the planer the work moves past the tool. In the shaper the tool moves across the work. This is especially useful in short-stroke work. Like the engine lathe and the planer, the shaper is

particularly useful where comparatively few pieces of a kind are to be made. Shapers are very useful in job and repair shops and are a standard machine in railroad and similar maintenance shops. They are also used in cutting both internal and external keyways and can be used for emergency gear cutting by providing proper tools and an indexing mechanism. Round or contoured surfaces can be produced by following scribed outlines or by

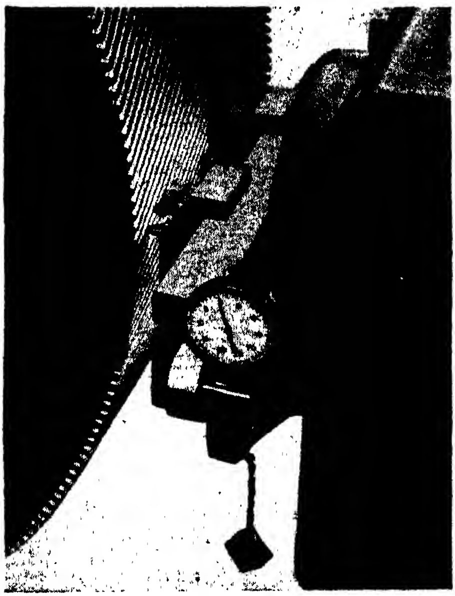


FIG. 31.—Testing the accuracy of the gear teeth after shaving.

If the linear pitch of the gear teeth (measured over several teeth as shown) is incorrect, the dial indicator will move away from zero. The size of the whole machine can be judged from Fig. 32.

turning the work under the tool. This is frequently done on crown brasses in the railroad shop.

Slotting Machines.—The slotting machine is practically a shaper with a vertical movement of the ram. Small slotters are used in toolroom work and are called "vertical" shapers. This is largely because the big shaper so widely used in railroad shops was not so accurate or so refined a machine. In small shops the small slotters are very useful in making punch-press dies and similar work. In large sizes the slotter has the same

advantage as the vertical boring mill, in that the work can be easily adjusted on the horizontal table under the tools.

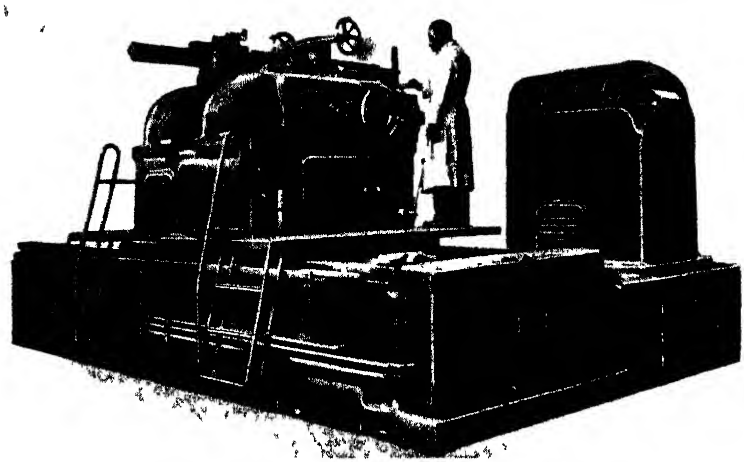


Fig. 32.—Large 96-in. gear-shaving machine built by the National Broach and Machine Company.

Figures 30 and 31 are taken from the other side of the machine. The size can be appreciated by comparing the machine and the operator.

Fig. 33.—Large cylindrical grinding machine made with either hydraulic or mechanical feed.

A better idea of the grinding operation can be obtained by studying some of the machines and work shown in Chap. VIII.

These features have made the slotter a favorite in railroad shops. With a rotating table, crown brasses and driving boxes can be machined as readily as in a shaper. Slotters have also

Fig. 34.—Landis grinding machine designed for grinding crankshafts for large engines. Although similar in design and construction to Fig. 33, it is especially fitted for crankshaft work.

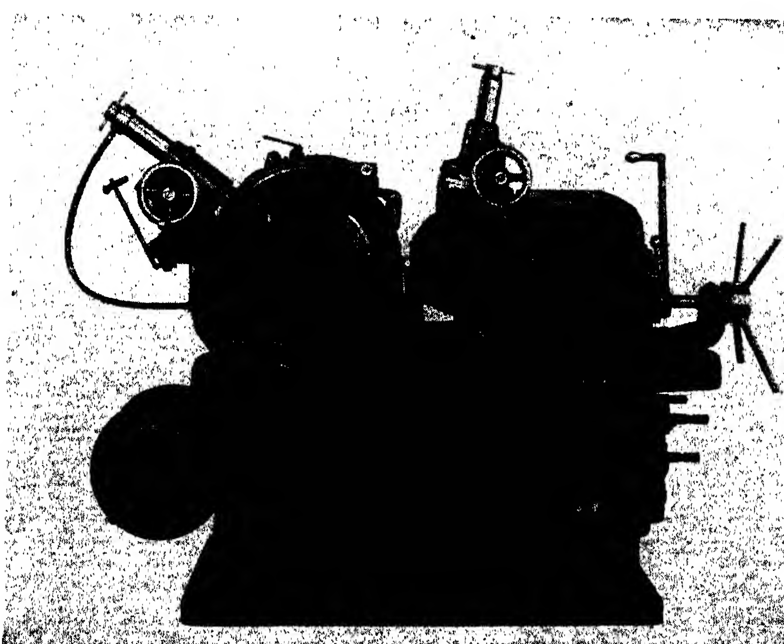


Fig. 35.—A Cincinnati centerless grinding machine.

Here the rod or shaft to be ground passes between the two wheels shown. The wheel on the left does the grinding while the one on the right supports and revolves the work against the other wheel. These machines can feed the rod through for continuous work.

been used very successfully in cutting large gear teeth, both internal and external.

Boring Machines.—Boring machines and boring mills are frequently confused. Although both do boring work, they are quite different and operate in different ways. Boring machines have horizontal spindles carrying boring tools; these revolve while the work is stationary. In the boring mill the tools are stationary, and the work revolves on a horizontal table. The boring spindle is mounted horizontally on a rigid column support on which it moves vertically to reach different positions on the work. The

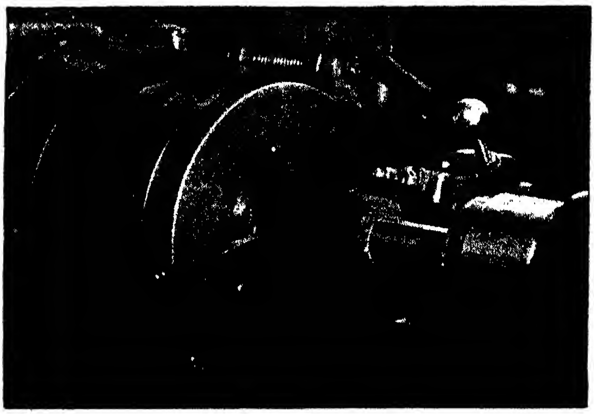


Fig. 36.—**Head of a Heald internal grinding machine for small holes.**

The work and the grinding wheel both revolve. The size of the wheel used depends largely on the size of the hole to be ground. The grinding wheel touches only one side of the hole as the work is revolved.

work rests on a horizontal table that has two movements. Frequently there is a rotating table as well. The boring tools are fed into the work by the movement of the spindle carrying the tools. The table movements in line with the spindle and across the bed are for positioning the work. Old-type boring machines had boring spindles at a fixed height and moved the work vertically as well as across the bed. This type is no longer built. The machine that most nearly resembles it is one that is called a "cylinder-boring machine." It has a fixed-position spindle, and special fixtures that keep the work at the correct height.

The modern type of horizontal boring machine with the movable spindle is known as the "Lucas" type from the pioneer

builder. It is very convenient for locating and boring holes in fixtures and in machining and milling a large variety of work. It is not a high-production machine, but it is extremely useful in such general machine-shop work as that found in railroad and

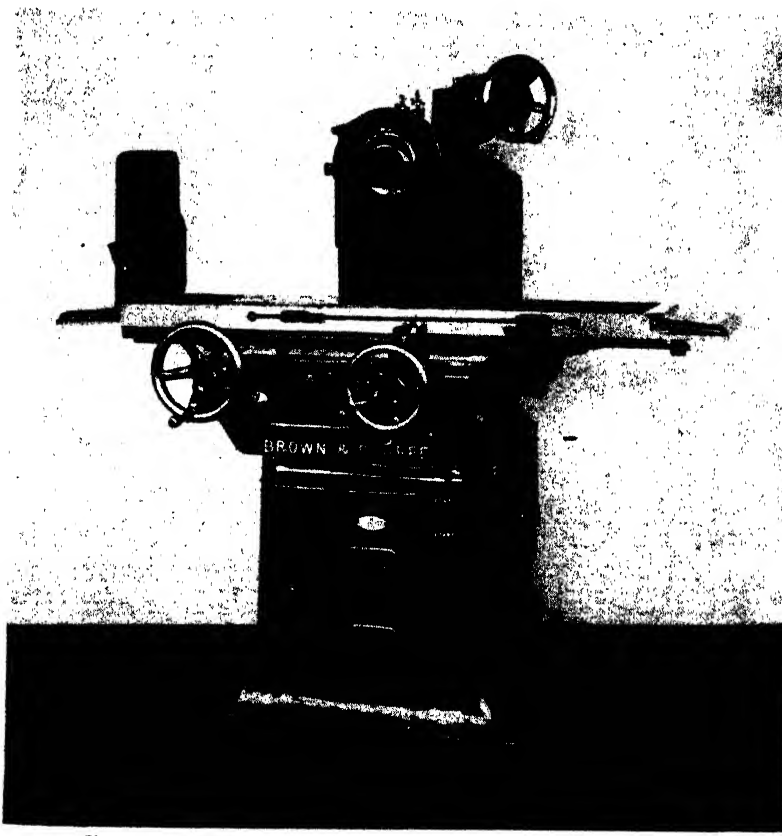


FIG. 37.—A Brown and Sharpe standard type of surface grinder.
The work is moved under the grinding wheel that grinds on its outer surface, or edge. The grinding head is adjustable vertically.

maintenance shops and in manufacturing where the work is varied and the quantity comparatively small.

Boring Mills.—Boring mills have a horizontal table that revolves the work under the cutting tools carried on a crossrail over the table. Modern boring mills usually have a sidehead which converts them into vertical turret lathes. This is in fact the designation of the Bullard boring mill of this type, which

the Bullard Company has built for many years. These machines handle what is known as "faceplate work," so called because the work is fastened to the revolving table which is the same as the faceplate of a lathe. An engine lathe of similar capacity can do any work that can be machined on the boring mill by

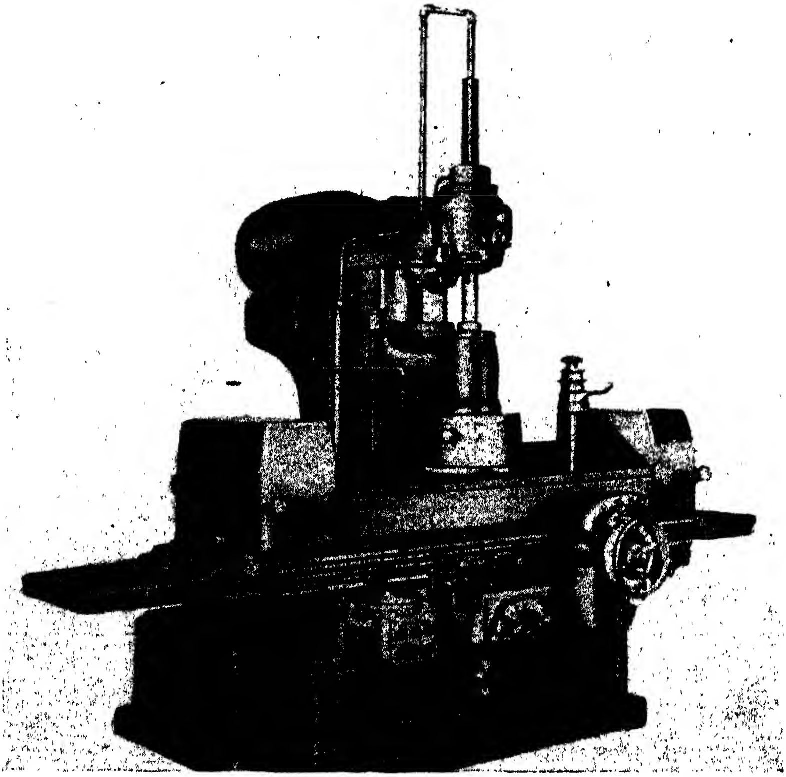


FIG. 38.—Pratt and Whitney vertical-spindle surface-grinding machine.

As with the other grinding machines the table carries the work past the grinding wheel. Here the wheel has the same action as in the face-grinding machine shown in Fig. 40 as the face is used against the work. The only difference is that the spindle in one is horizontal and in the other, vertical. The choice depends largely on the size of the work to be done. For very large work the machine shown in Fig. 40 has several advantages.

clamping the work to the faceplate. The boring mill is, however, more convenient for locating and fastening the work and is preferred by all machinists on work that is large but is not long enough to interfere with the crossrail. On long work the engine lathe must be used.

Milling Machines.—Milling machines use rotary cutters and feed the work past them, in most cases by screw or by hydraulic mechanisms. The milling machine can produce flat, curved, or other surfaces by using proper cutters combined with suitable movements of the work table. Irregular work, gear teeth, and

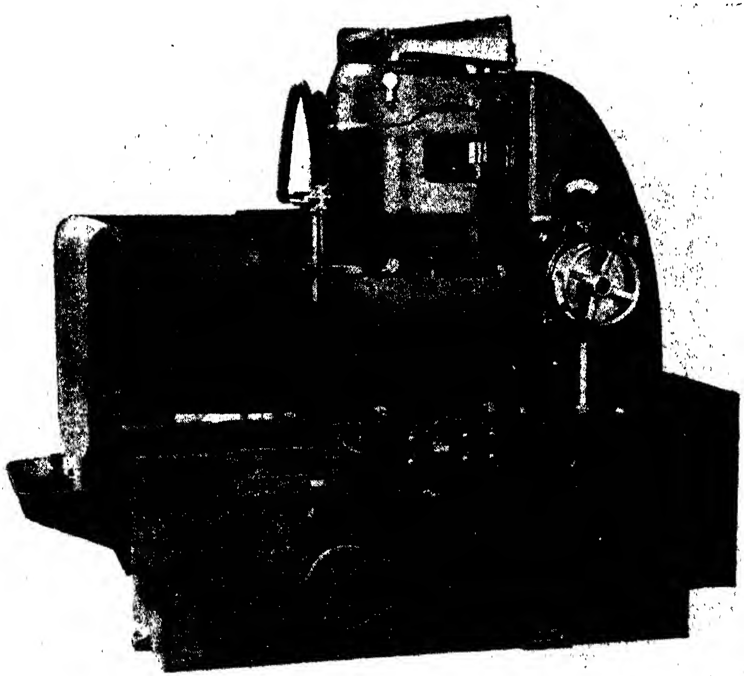


FIG. 39.—Blanchard rotary surface grinder.

This uses a cup wheel on a vertical spindle the same as the Pratt and Whitney grinder but the work is held on a rotating table instead of on one that reciprocates or passes the work under the wheel in a straight line. The rotary table is mounted on a slide that brings it out from under the wheel for loading and then carries it back into working position. Being rotary, the operation is continuous after it is under the wheel. Because of the combined rotary motions of the wheel and table, the surface left by grinding has a different appearance than that of the other machine but this does not affect the accuracy in the least.

other forms are produced by correct combinations of cutters and work movements.

Milling machines are made in many types for a large variety of work. Most of them are for general machine work and are very adaptable. Others are highly special with numerous cutters in different positions to machine certain portions of the work in correct relation to the others, as the work passes under the

cutters. In most cases the work moves past the cutters in a horizontal plane, but in some, the work rotates past the cutters or between milling cutters.

Hand millers are usually confined to small work. In some cases they are as efficient as highly special machines when first cost and machine overhead are considered. However, much depends on the speed and skill of the operator. In toolroom work the universal type of miller is indispensable for such work as making special twist drills, reamers, and milling cutters.

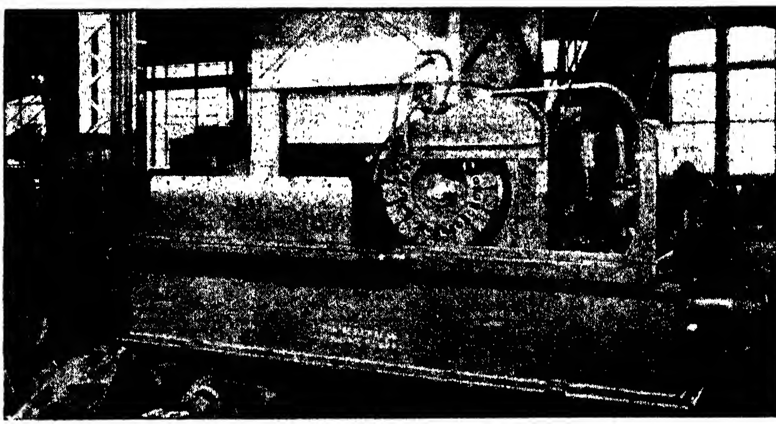


FIG. 40.—A Diamond Machine Company face-grinding machine utilizing the face of the large grinding wheel shown.

These large wheels are made up of separate segments both for ease in manufacture and to allow easy replacement of segments. The spaces between the segments also permit a slight cooling action by avoiding continuous contact between work and wheel. This closely resembles the so-called rotary planer in which the grinding wheel is replaced by a milling cutter.

In the job or experimental shop it can cut gears or cams of almost any description.

Gear-cutting Machines.—For cutting gears there are specially designed milling or shaping machines. Used with a rotary cutter they fall into the milling-machine class. Gear shapers or planers such as the Gleason bevel gear planer or the Fellows gear shaper are special machines of these classes. These machines are very rapid and produce gears with greater accuracy than was previously possible. Gear hobbing machines are special types of milling machines.

Grinding Machines.—For grinding there is a large variety of machines of many types. Plain cylindrical grinders are for such

work as piston rods, calender rolls, armature and crankshafts, and other cylindrical parts. Parts with curved or other irregular forms are often ground with wheels having their periphery shaped in a similar manner. These are usually ground between centers.

Fig. 41.—Horizontal-spindle surface grinder.

This uses the periphery of the grinding wheel. The work reciprocates under the wheel as in the Pratt and Whitney machine. This is a Mattison machine. The work is on a slide of a heading machine that weighs 3 tons.

Ground holes are produced by comparatively small wheels revolving at high speed inside the work which turns at a much slower rate. Machines are also built that make it unnecessary to hold the work between centers for either outside or inside work. These are called "centerless" grinders. Where they can be used, they save most of the time usually consumed in loading and unloading work.

Flat surfaces are ground in a variety of ways. The most common machine moves the work back and forth under a grinding wheel. They usually have horizontal spindles and grind with the periphery of the wheel. Machines are also made with a vertical spindle and use a cup wheel, either solid or made up of segments, depending largely on the size of the wheel. Another variety uses the same type of wheel but holds the work on a

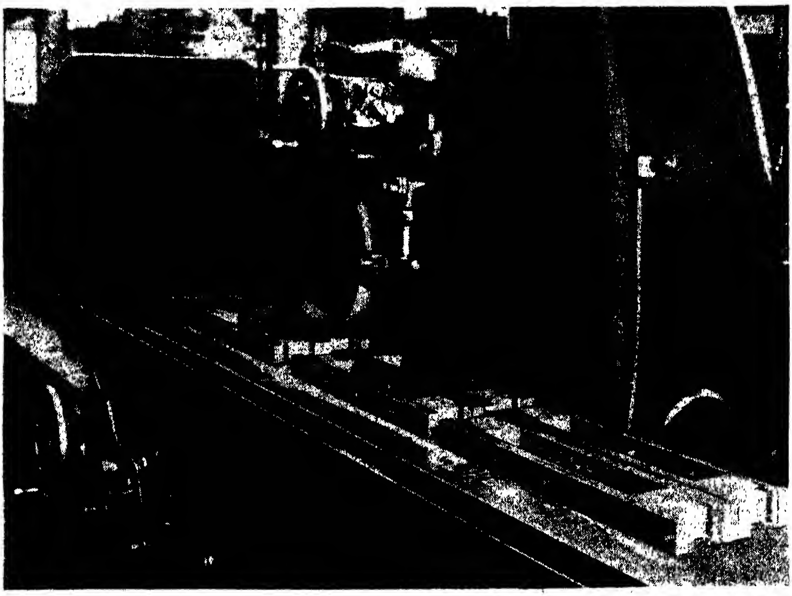


FIG. 42.—A machine similar to Fig. 41.

This is shown grinding 12 wheel-head guides. These are arranged in pairs and are held by a magnetic chuck on the machine table. Work is arranged in this way to permit long table travel without reversal and is known as "string" grinding. Planer work is also set up in this way where it is possible since it saves time.

rotating table somewhat resembling a boring mill. As the table revolves, it carries the work under the grinding wheel. Still another type uses the cup wheel on a horizontal spindle and has a planer table which carries the work past the wheel.

Disk grinders are also used in surfacing work of many kinds. The abrasive disk consists of paper or cloth cemented to a metal plate. These plates are usually mounted on horizontal shafts, but in some cases vertical shafts are preferred. Thus the abrasive disk is brought into a horizontal position so that the work is simply laid on the disk as it revolves. It is held against rotation

by hand or by a suitable fixture. Disks on horizontal shafts are sometimes mounted in pairs so as to grind two surfaces of any work passed between them. These machines do work very rapidly and are used largely where accuracy is not the first consideration.

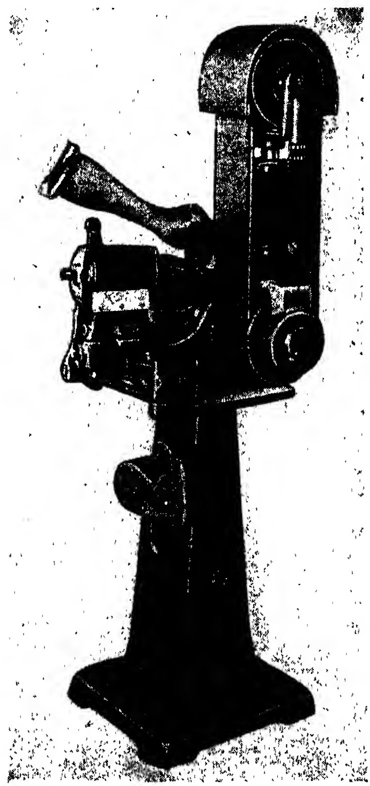


Fig. 43.—Production Machine Company surfacing machine using an abrasive belt running over a supporting metal plate behind the belt. The work to be ground is held against the belt and can be surfaced at a rapid rate.

Broaching Machines.—Broaching is the surfacing of work by means of a series of small cutting edges on tools which are forced through or past the work. Each tooth removes a small chip and gradually finishes the work to the desired shape and size. Broaching machines are driven either by screw or by hydraulic pressure to force the broaches past the work. The power required depends on the number of cutting edges in contact with the work at one time and the amount of metal removed.

Starting as a method of enlarging holes and producing square, hexagonal, or irregularly shaped holes in work, broaching is now used to machine a variety of flat and curved shapes. Some of these machines are large and have enormous power and metal-removing capacity. An extreme example is the machin-

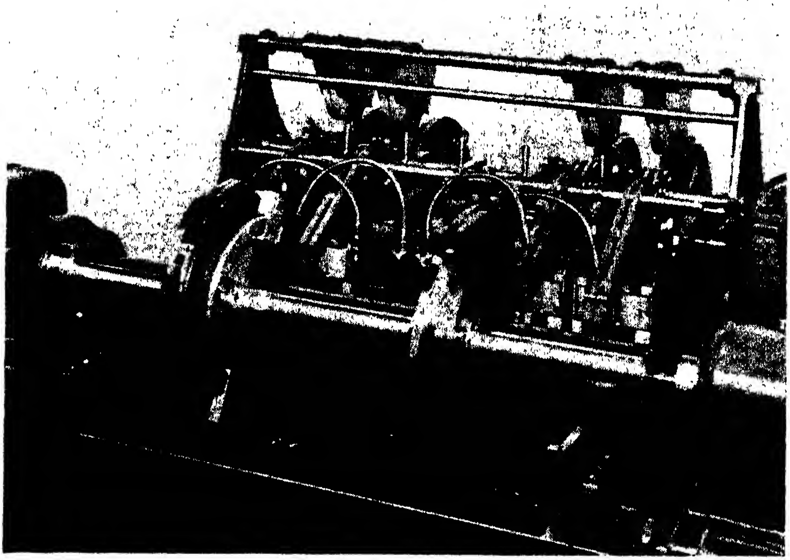


FIG. 44.—Machine lapping of aircraft-engine cams.

Another special machine developed for the aircraft-engine industry is the cam-lapping machine shown here. It is known as the Cam-O-Lap, made by the Norton Company. Two sets of cams for radial air-cooled engines are shown in position in the machine. The cams are mounted on special carriers that revolve them in contact with the abrasive belts shown at the rear. The shaft carrying the cams is placed in the machine on the ways shown under it at each end and then is connected to the rotating mechanism. As the cams revolve, the lapping belts move back and forth under control of similar cams seen at the back. This enables contact with the work to be kept and does not permit an appreciable amount of metal to be removed. The object of the lapping is to produce a very high finish and to ensure long life to the cams that control the valve mechanism of the engine.

The abrasive paper used is backed by pads to provide the proper cushion. Kerosene is used as a lubricant on the work. The changing from one type of cam to another simply requires the replacement of the master cams at the rear and of the tier arbor. The cams have been ground previous to lapping.

ing of the top, bottom, and other outer surfaces of an automobile cylinder block at a single pass through the machine. The process has many diversified applications with which builders of broaching machines are more familiar than anyone else. Much depends on the strength and rigidity of the work to be broached, the methods of holding it, and the kind of tools to be used. In some cases, as in the cylinder broaching machine, the work is carried past stationary broaches in a straight line. This is, in fact, the usual method.

In some kinds of work where large quantities of small parts are needed, the broaches are carried on a rotary table with the work held in suitable fixtures around the outside. Another method is to clamp the work on a large revolving table which

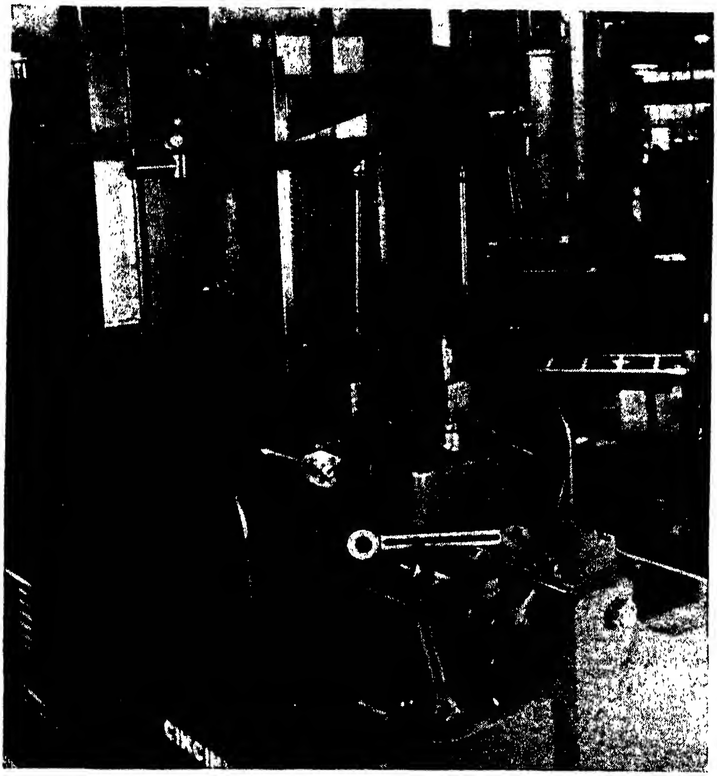


FIG. 45.—Broaching. A vertical Cincinnati machine surfacing the sides of articulated or linked rods of radial-aircraft engines.

The broaching tools—or broaches—are seen on the vertical slide of the machine. A broach is a series of chisel points—or small cutting edges—something like an enlarged file. The teeth are staggered so that they will break up the chips. The finishing teeth at the top are continuous in order to remove any small irregularities that might be left by the smaller teeth. The broaches are made in sections and therefore can be easily replaced when dull or broken. The work must be firmly held. It is moved back on the return stroke of the slide. This finishes the side of the rod at one pass.

carries it past, or between, stationary broaches on the outside. These are, however, unusual applications of broaching. A typical example of standard broaching is seen in Fig. 45.

It is evident that the tools used in broaching are expensive to make. When used on rough materials, as in the case of the

cylinder block, the leading teeth of the broach lose their keen cutting edge quite rapidly and must be sharpened frequently. For this reason the broach is made in sections so that parts can be replaced as they become badly worn. Sections can be advanced as they wear, new sections being added for the finishing of the work.

As in all kinds of work, it becomes necessary to count the cost of the machine and the cutters, as well as their maintenance, before deciding on the method to be used in machining. The time the machine is idle, while the cutters are being changed or sharpened, or for any other reason, must also be considered in deciding on the method to be selected. If the rate of production is high enough and the quantity needed is sufficiently large, the broaching method has many advantages.

Grinding.—Grinding, another standard method of finishing flat surfaces, must always be considered. Although grinding was originally thought of as only a finishing operation in which very small amounts of metal were removed, it is now a direct competitor of the tool-carrying machines even in removing metal from rough castings or forgings.

As with the milling machine, the grinder is made with both horizontal and vertical spindles, and many of the same characteristics are present in both machines. The horizontal-spindle machines generally use the outside or periphery of the grinding wheel, and the vertical-spindle machines use the side or the end of the wheels in the same way as milling cutters are used in similar machines. Exceptions are the horizontal machines in which the face of the cutter or wheel is used. This type of milling machine was formerly known as a "rotary planer," and has already been illustrated.

The end-grinding type of machine is used for roughing as well as finishing and is made in three forms, besides the well-known disk grinder. Both the Blanchard machine with its rotary work table and the Pratt and Whitney machine with its reciprocating table were early in the field of machines for surfacing work with the grinding wheel. These were shown previously. With the Blanchard type of machine, the work is carried under the grinding wheel by the rotating table. The table can be moved forward on sliding ways for loading and is then fed back under the rotating cup wheel. The combination of the rotary table and

the end grinding wheel gives a pattern of curved feed marks on the work which is different from those produced on the Pratt and Whitney machine. Although the appearance of the work differs from that produced on other machines this does not indicate that the surface is not all that can be desired so far as accuracy is concerned.

The third type, with the horizontal spindle and the end wheel, was shown in Fig. 40. This gives the same type of feed mark as the Pratt and Whitney machine. The only difference is that one grinds on the top of the work and the other on the side face. As can be seen, many kinds of work can be done on any of these machines. Economical manufacture depends on selecting the one best fitted for the particular job in hand. As pointed out before, the selection may be influenced by the availability of certain machines, their cost, and the familiarity of the workmen with the different types. The examples of work shown can all be done in different ways. Selecting the method that best fits all the conditions involved is the job of the production engineer.

CHAPTER II

STANDARD METHODS AND MACHINES

What Are Standard Methods?—The use of the term "standard" as applied to machine tools or to methods should not be taken too literally. Shop practice, even with the same or similar machinery and tools, varies widely among shops. Many use vertical boring mills on work that others prefer to do in an engine lathe or turret lathe. The same is true in milling-machine practice where some prefer face milling and others use the slabbing cutter for similar work. Again we find some shops milling flat surfaces where other shops use planers or shapers. Some gear makers use hobbing machines where others prefer gear planers or shapers. These machines, however, are all standard for the work for which they were designed.

On the other hand, emergency methods are understood to include the use of machines or tools on jobs that are not normally done on those machines. It often happens that the emergency methods are less efficient if we count only the time required for the work. But, when there are no facilities available for doing the work by the usual methods and when time is a factor in securing production, such comparisons carry no weight whatever. When there is an urgent demand for a product, the exact cost is comparatively insignificant and the methods by which the job can be done promptly become exceedingly important. Knowledge and experience that enable a shopman to devise new methods or to utilize machines already available and so avoid delay are extremely valuable assets and should be well rewarded.

Standard Cutter Speeds, and Feeds.—Nor should we place too much reliance on what are called "standard" cutter speeds and feeds. Both of these change from year to year and frequently from month to month. Ultimate cutter speeds depend on the cutter, the material, and the way in which the work can be held in a machine. The rigidity of the work and of the machine, the power available at the cutting tool as well as the strength of

the tool material all have their effects. The feed must be sufficient to enable the cutting edge of the tool to get a good "bite" in the material being cut, or the cutting edge will slide over the work until the feed forces it in deeper than intended. Then the tooth or cutting edge breaks or digs in with unsatisfactory results. Unless the cutting edge has a good bite, it soon dulls and cannot do good work. In the case of milling cutters, *each tooth* must get sufficient bite to get best results. This means that the number of teeth in the cutter should be proportioned to the feed per tooth, and this is why we now see many milling cutters for aluminum and similar metals with but two teeth, or even only one.

Some idea of the changes that have taken place in metal cutting may be had by comparing the power used in shops of fifty years ago with those of today The shop in which the writer learned his trade had four stories and employed about fifty men. The Corliss engine in the basement transmitted its power by belting to long line shafts on each floor. The belts and shafting absorbed a large percentage of the 25 hp. of the engine. Today we put from 5- to 10-hp. motors on many medium-sized single machines, and there are some cases where a single machine is driven by a 100-hp. motor all its own.

Cutting speeds and feeds have increased in a somewhat similar manner, because of the discovery of much better materials for cutting tools. These in turn made it necessary to increase the strength and rigidity of the machine tools so that the advantage of the new tools could be utilized. This development has been similar to the rivalry between armor plate and the projectiles designed to pierce it. These newer tools made it necessary to put more power into the new machine tools; even now some of the newer tools will stand more than the machines in which they are used.

When Mushet and high-speed steels succeeded carbon-steel tools, the machine tools had to be redesigned to have greater strength, rigidity, and power. The advances made with the newer cutting tools such as Stellite and the carbide tools have again challenged the builders of machine tools to increase their capacities in various ways. What cutting speeds will be attained when machine tools can drive the newer cutting tools to their limit, it is impossible to predict. This applies both to the harder

metals as alloy steels and to aluminum and magnesium. In the latter field, however, we already see cutting speeds as high as 18,000 ft. per minute, and we are by no means sure that this is the limit. In some of the airplane plants, speeds of 8,000 and 10,000 surface feet are now fairly common for these softer metals. To go much beyond these raises the question of bearings for machine spindles and other problems.

At this time it looks as though some types of machine tools of the future may have to be designed in two distinct classes: those for ferrous alloys and those with a much higher speed for aluminum and the softer alloys. It seems hardly likely that these extremes of speed can be successfully combined in a single line of machines. We must, however, remember that cutting speed and feed are only two of the factors that make up machining costs. On short cuts, as in average milling operations, high speeds may save only a small percentage of the total time; for in many cases, the handling time plays a major part. This means that more attention must be paid to the design of work-holding fixtures so that the handling time may be reduced to a minimum.

These extremely high cutting speeds have been developed in milling operations largely because nearly all the machine work on airplanes is milling and not turning. There is, however, good reason to believe that milling speeds can be much higher than those for turning because the action of the milling cutter tooth is intermittent while that of the turning tool is constant. This gives the milling cutter tooth time to cool between cuts, while the turning tool is constantly buried in the metal. This constant contact heats both the metal and the tool, but with the milling cutter nearly all the heat seems to go into the chips. Strangely enough, experiments at the Bell Aircraft Corporation showed that the greatest heat was generated at a cutting speed of 3,000 ft. per minute; at higher speeds the heat decreased. In fact, it was impossible to reach a speed high enough to bring the heat back to that generated at 3,000 ft. per minute.

With widely spaced teeth (usually but two on cutters up to 24 in. in diameter) and with each tooth having a chip of from 0.006 to 0.012 in., very high speeds have been obtained with feeds running up to unheard- of figures. In fact no one yet seems to have reached the high limit of cutting speed on soft metals. There may also be mechanical difficulties in securing

feeds to the maximum of the cutters. A chip of 0.10 in. at 10,000 ft. per minute gives a feed of 100 in. per minute. Even higher feeds have been secured.

Changes in Cutters.—Radical changes have been made in the cutters themselves. They are now being made with cast or malleable iron bodies or centers, some of Meehanite and some with bodies cut from steel boiler plate with the tools welded at two points on the circumference.

Cutting edges too have undergone radical changes. For milling or turning steels, especially armor plate or where there are interrupted cuts, it has been found that tools with a 10-deg. negative rake stand up much better, especially when carbide tools are used. This negative rake gives an excellent support to the cutting edge and tends to prevent crumbling. Some find that zero rake, that is, with the cutting edge radial from the center of the cutter, does even better so far as finish is concerned.

It seems logical that the negative-rake tools take more power than the others, but tool life is the important thing in most cases. Some contend that the same practice should be extended to the cutting of softer metals, but this is not often borne out. With aluminum and magnesium the positive-rake cutters stand up splendidly and seem to be well adapted to the work.

These developments are mentioned in more or less detail to show that we cannot let ourselves feel that the machines and methods we now consider standard will remain so for any length of time. If we bear this in mind and also keep our minds open to receive the changes that are bound to come, we shall utilize our machine equipment with a much higher percentage of efficiency than if we accept last year's practices as the best possible.

On the other hand, what might be considered emergency methods in a well-equipped shop might be adopted as standard in shops lacking some fairly common types of machine tools.

Screw Threads.—Screw threads play an important part in all mechanisms and in many products. They vary widely in size and shape depending on the use for which they are intended. Watch threads vary from 110 to 254 threads per inch; micrometer screw threads are 40 per inch; and a standard 1-in. bolt has 8 threads per inch. The threads of many mechanisms are much coarser than that.

The shape of the thread also varies widely from the 47½-deg. British Association thread to the 60-deg. angle used in most threads except the British Whitworth, which is 55 deg. Then there are the Acme thread and the worm thread, both being 29 deg. but having different depths. Square threads, Dardelet threads, and the round threads used in lamp bases, as well as the threads used on glass bottles, must all be considered. Most important of all is the accuracy that is necessary in making threads of different kinds. The round threads are frequently known as "electric" threads.

In the early days, many tap threads were cut by wrapping a string around a piece of steel and filing the thread to the pitch shown by the string; now the basic machining method for thread cutting is the use of the engine lathe. Here the thread is "chased" with a single-point tool moved along the lathe bed by the lead screw on the lathe, turned at the proper rate to produce the pitch of thread desired. By changing the gearing that drives the lead screw from the lathe spindle, threads of different pitches can be produced.

Chasing threads in the lathe is not a production method but is confined to special work or where but few pieces are needed. It is, however, possible to cut threads in the lathe much faster than might be realized by those not familiar with the methods of good lathe men.

In mass production the cutting of threads is usually done with dies or by milling. The latter is a comparatively new process as now carried on. Milling with a single milling cutter was practiced by Eli Horton in Windsor Locks, Conn. He cut the screws for his lathe chucks in this way as far back as 1860. There are also thread milling machines today which use single cutters, mostly on fairly coarse threads. The modern method is to use a cutter with multiple teeth, called a "hob," which mills the short threads generally needed at one revolution of the work or one revolution of the milling head in the planetary types of machines. Where the threads are of any considerable length, the milling cutter of the type used by Horton still prevails.

Most outside thread work is done with dies, either solid or adjustable. Many modern dies have separate cutters or chasers which can be adjusted for size or which can be easily removed

for sharpening. For small work, dies of the button or acorn types are used.

Collapsible dies and taps are also used largely in some classes of work. These move the chasers away from the work as soon as the thread is cut and do not have to be backed off by running the work backward.

Rolled Threads.—Outside threads are also produced by rolling a bar between dies with grooves to form the proper thread shape. This method forces the metal up from the bar into the dies instead of removing part of it by cutting. Unless the size of the bar is reduced where the thread is to be, the threaded portion will be larger in diameter than the body of the bar itself. The first thread rolling was done in circular dies with a small male die inside a larger female one. These were set off center, the closest distance between them representing the diameter of the finished thread.

Round dies gave way to flat ones quite early in the development of the process, the bar being rolled between two flat die plates.

Thread rolling was used first in making rather rough work such as track bolts, but it has since been used in finishing such accurate threads as those in micrometers.

Threads are also cut in what are known as "automatic chasing lathes." Here the thread is cut with a single-point tool, but the operation is made automatic. The tool feeds into the cut a given distance for each pass and reverses automatically for the return to the beginning. At the same time, the tool is automatically withdrawn from the cut and is fed in again at the start of the next cut. This method has largely given way to thread milling.

The main difference between this and the thread miller is that the latter cuts the full depth at one pass while this machine takes as many passes as necessary to produce the full thread. Each cut is taken in a short time so that there may not be much difference in the total time required.

Threads on sheet metal, such as the caps for cans and bottles, are made by passing the threaded portion between rollers having the form desired. This kind of thread work requires special machines made by manufacturers of can-making and similar machinery.

Formed Threads.—Threads can also be formed by internal or external pressure by the use of either liquids or rubber. This method requires special equipment, which is expensive and complicated, and is not usually so economical as that of rolling. It is used only in special cases.

Threads can also be formed in die castings or in plastic molding by forcing the material around threaded parts and then unscrewing the parts after the material cools. Except for fairly coarse threads, it is usually better to put threaded inserts in the molds and use these instead of threads cast integral in the piece.

Threads can also be formed on some materials, such as celluloid tubes, by forcing them into threaded dies or nuts which are heated sufficiently to allow the material to change its shape. All these methods require experience if success is to be expected.

Precision threads, either for purposes of measurement or to secure commercially perfect fits, are now usually finished by grinding. The thread-grinding machine resembles the thread miller, but the milling cutter is replaced by a grinding wheel. As with the milling cutter, the face of the wheel is shaped to the proper profile for the thread to be produced. It should be fed at the appropriate rate as the work revolves as with the thread miller.

Ground Threads.—Used on hardened screws, the grinder corrects any distortion in either lead or diameter resulting from the heat-treatment. It is also possible to grind threads from the solid in either hardened or soft stock. Taps are made by fluting the blanks, hardening them, and then grinding the thread. This completely eliminates any danger of distortion as when taps are hardened after the teeth are cut. As flat dies for thread rolling are also ground from the plates after they are hardened, distortion is avoided.

Studs of high-grade and heat-treated steels are threaded by grinding after being heat-treated. These are used largely by builders of airplane engines. The threads can be ground in from two to four passes of the grinding wheel, which would have been impossible without the present development in the making of grinding wheels. These studs are ground very rapidly from the solid—some operators claim as rapidly as they can be cut in any other way.

As with all other machining operations, the successful manufacturer must select the method best suited to his particular product and the conditions under which it is made. Here is where broad experience comes into play and can save much time and expense if it is thoroughly considered before the methods to be used and the equipment to be bought are decided upon.

Designing for Manufacture.—Although the selection of suitable machine equipment is necessary to secure the economical production of any article, the design of the article itself has much to do with the cost of producing it. For this reason it is important that the details of the design be inspected by the shopmen who are responsible for production costs. They know what machine equipment is available to produce the article and also the skill of those who must produce it.

It frequently happens that a few minor changes in design will greatly reduce the number or the difficulties of the operations. In other cases it may be necessary to make changes that may amount to a complete redesign of the piece. In any case the production men should have the opportunity of studying the design, both as to the operations to be performed and the tolerances that are necessary. This not only reduces cost in most cases but also makes for harmony among the different departments.

With the wide variety of machine tools now manufactured and the many effective, if unusual, methods of utilizing the older and simpler machines, several methods are usually available for almost every job. A study of these methods, both standard and emergency, should be of real assistance in solving manufacturing problems.

Effect of Design on Machining Methods.—The design of any part of a mechanism and the machining methods that must be used to produce it are closely related. It frequently happens that a slight change in design will not only reduce the difficulty of manufacture but also permit the part to be made on a machine that is already available. Close cooperation between the designer and the shop can often avoid the necessity of purchasing new machine equipment. Frequent consultation between the designer and the production department can save time and money for all concerned.

If the nature of the work demands an intricate design, the production man will find a way to make it. This usually means added expense in manufacture and may easily influence the price of the article and likewise its market when it is produced. Often it will save money to build an intricate design in two or more parts instead of in one piece as originally planned. Welding and brazing can often be of great help in situations of this kind.

It is very important that, before a design is finally decided upon, it be carefully studied by the production department. When this is done, it is often possible to reduce costs by simplifying operations or by utilizing machines already available instead of increasing the machine overhead by buying new ones.

Materials.—Selection of materials is one of the most important factors in designing and building a machine. With iron or steel, or ferrous metals, the choice must be made between iron or steel castings, steel forgings, sheet or plate metal, or structures built up by a combination of plate and castings. For some parts, aluminum, bronze, magnesium, or other alloys may be more desirable. Here again the question of castings, forgings, or built-up structures should be carefully considered.

Still another alternative now faces the designer in the shape of plastics of various kinds. Even glass and impregnated wood should be considered in some situations. The selection of materials should be based on strength, weight, ease of manufacture, and availability, not overlooking such factors as deterioration by corrosion or other means.

It frequently happens that the best material for the purpose is not available or is too expensive. Then the best substitute must be found. The final selection must also consider the machines available and the familiarity of the workmen with both the machinery and the material selected.

Welding.—The use of welding in connection with work machined in various ways has opened many new possibilities for savings in both materials and labor. Welding has perhaps done more to change our older methods of construction than anything else that has happened in many years. Fixtures that formerly required the making of patterns and a casting before machining and finishing are now easily made up from welded steel plate. These can be completed in less time and at lower cost than by the old method. Frames and beds for machines and apparatus

of many kinds are now welded instead of being cast. Combinations of castings with steel plate are also used. No rule can be given that will fit all cases. The individual requirements and the equipment available should be carefully considered in each case.

One governing factor in determining whether to use cast or welded structures is the number concerned. Where only a few are required, the welding process saves the cost of making patterns, which are usually very expensive. With quantity production the cost of the pattern is distributed over a large number of parts and may be more desirable. On the other hand, welded structures may have advantages, as in the case of the press brake and similar machines, which warrant the individual welding of the frame of each machine. Then too, welding has been developed by the use of fixtures so that it has become a manufacturing operation.

Principles of Machine Operations.—In considering the methods to be used in machining any given piece of work it is well to remember that the principles involved are rather simple. All turning and boring operations, for example, were first done in the lathe, and all special machines used for those operations embody the same principles. The vertical boring mill, for example, is practically a lathe stood up on end with the faceplate in a horizontal position. Some of these, such as the Bullard, are called "vertical turret lathes." For what we may call "faceplate work" they are more convenient than the horizontal type of lathe. They are limited by the length of the work but have been made up to 40 ft. in diameter.

In the same way the horizontal boring machine operates like a lathe except that the revolving tool is fed toward the work. The spindle travels in its bearings, while the work remains stationary.

All special boring machines, such as the precision, single-point boring machine (made under several names), involve the same principles. In most of these the single-point tool revolves with the spindle, and the work, held in special and convenient fixtures, is fed over the boring bar. Accuracy is obtained by using rigid bearings supported without spring or vibration so that the cutting tool revolves in a true circle. The work is held in specially designed fixtures that are easily and quickly

operated, and the work is fed over the boring cutter automatically and on ways that are very accurate.

Similar work can be done, and has been done, in both the engine and the turret lathe when the same accuracy existed in the bearings and the ways of the machine. An example of this is found in Chap. V, which shows how extremely accurate work was done in the Kelvinator plant some years ago. When these special boring machines are not available or when production quantity does not warrant investment in one of the very convenient special machines, the work can be done in the lathe as will be shown. It is, however, necessary to have the lathe spindle perfectly true and the bearings well fitted and to be sure that the work can be moved over the cutter accurately. The work-holding fixtures should be well designed and accurately made to secure satisfactory results. One reason for the success of these special machines is found in the skill and accuracy with which the work-holding fixtures are designed and built. These make it possible to handle the work faster than can be done in improvised fixtures. But it is well to remember that really accurate work can be produced in the same way on any good lathe that is available. Similar results can be obtained by revolving the work in the chuck and feeding the boring tool into it. In fact, this method is used by the special machines in some cases. But accurate spindles, good bearings, and freedom from spring and vibration are necessary where good work is desired. Overhang of either the spindle or the work should be kept to a minimum in any machine for this sort of accurate work.

Overhang does not always receive the attention it should even in some of the more modern machine tools. Fifty years ago it was common practice for the planer table to overhang the bed at each end of a full stroke, or even at less than full stroke. Now all planers have beds that are twice the length of the table, plus a little extra. There are still several other types of machine tool in which the tables overhang their support to a marked degree, thereby lessening the possibility of doing the most accurate work on them. Overhang should be carefully watched whether the work is being done on new and special machines or on machines that have been pressed into service for the job.

Substantial bearings, well supported in their housings, are also essential. In these days of antifriction bearings, many seem

to forget that accurate bearings can be made with plain surfaces of babbitt, bronze, or even cast iron. All large cylindrical grinding machines have plain bearings, indicating that it is still possible to use them successfully. Antifriction bearings are convenient to use and are essential in many places. They undoubtedly save power in many cases and, as a rule, require less attention than plain bearings. But plain bearings do not necessarily bar a machine from being classed as suitable for accurate work.

Using Multiple Tools.—The engine lathe is primarily a machine for using single-pointed tools for either turning or boring. Multiple turning tools have, however, become very common in all kinds of lathe work, especially in turning. Multiple-cutter boring bars are also frequently used in lathe work. The turret lathe, which is an outgrowth of the engine lathe, uses multiple tools for both turning and boring in many cases. One type of turning tool used in the turret itself is frequently known as a "hollow mill." Here the projecting teeth cut the metal away from the outside of the work while the part that is being turned enters the inside or hollow part of the tool. In some cases there is only a single cutting tool, held radially to the work by a body that supports the work as soon as the turning begins.

Multiple-tool boring bars are very common in turret lathe work for both roughing and finishing cuts; but, as previously stated, for the most accurate work the single-point boring tool well supported gives the most accurate results.

Some of the highly specialized single-point boring machines are built with two or more spindles so as to handle several pieces at one setting. These heads are also constructed to bore two holes in the same part at a given distance apart, for example, the two holes in the ends of a link rod in a radial airplane engine. This requires great accuracy in the building of the machine. Such machines have proved very economical where the output has warranted the initial cost. In case of necessity, the same result could be secured in an engine lathe with a fixture carrying two spindles at the right center distance and driven from the spindle of the lathe itself. It is not likely that this would be advisable in many cases, but it can be done and with good results.

Selecting Machines and Methods.—Many factors have to be considered before deciding upon the best method to use on any

given job. First cost of equipment as well as operating expenses is of prime importance when a new plant is to be built and equipped. The rate of production required also calls for careful consideration.

For a new plant the most suitable machines, from an economical viewpoint, should be obtained. But where the work is to go into a plant already established, it is necessary to see how many of the old machines can be used advantageously. Failure to do this adds materially to the first cost and sometimes postpones the date at which production can begin. When someone else is to pay for the plant, as was the case during the war effort, there are too many instances where work is delayed until new machines are procured. On the other hand, during the war, there were numerous instances where good mechanics utilized old machine equipment to great advantage in order to begin production at the earliest possible moment. Failure to do this has too often added materially to the cost of the war effort.

It is impractical to try to use machines unsuited to the work if others can be obtained in time. There are, however, many situations where production can be started on less efficient machines and then shifted to new equipment as it becomes available. When early delivery is essential, almost any makeshift method is preferable to delay.

On the other hand, there are many cases where the makeshift methods have proved to be even more economical than was thought possible. In fact, some of them have proved hard to beat even with special machines designed for the purpose. These, of course, are rare exceptions to the general rule.

It frequently happens that men become familiar with certain machines and methods and naturally suggest them for any work that can be handled in that way. They may not know of other methods or, lacking experience with them, prefer to stick to methods with which they are already familiar. This sometimes leads them to suggest high-cost precision machines for work that can be done more simply. Such suggestions are often prompted by demands for tolerances not justified by the work to be done.

The Machine to Use.—Selecting the best machine and the best method to be used in turning and boring should be governed by several factors: the machines available, the size and shape of the

piece, and particularly the quantity required. Both turning and boring can be done on the engine lathe, the turret lathe, and either the horizontal boring machine or the vertical boring mill.

If the work is small and only a few are required, the engine lathe will probably be the best to use. It is *possible* to turn on a drill press with a sweep cutter for turning, as will be shown later, but it is seldom advisable to use it if other machines are available.

The choice of the turret lathe over the engine lathe will depend largely on the quantity required. The question of available tools or the cost of making them must also be considered. With the standardized and simplified tooling now available for turret lathes, it may easily prove economical to set up a machine for a dozen or more pieces.

On large work, particularly the kind that would be fastened to the faceplate of an engine lathe, the vertical boring mill, often called a "vertical turret lathe," has many advantages. With its horizontal table, or faceplate, it is much easier to place work on it, to center the work, and to clamp it, than on the faceplate of a lathe.

With a lathe, the work must be supported by a hoist or by hand while it is being positioned and clamped. This usually takes considerably more time than positioning on the horizontal table of the boring mill. The boring mill with the turret on the crossrail or with the plain ram, coupled with the convenience of turning the piece by tools in the sidehead of the machine, makes a very convenient setup. It is, in effect, a turret lathe standing on its head.

Long work, however, must be done in the engine lathe. The height under the crossrail of the boring mill is necessarily limited, and a long piece would require the operator to use a stepladder. Although this is sometimes done, the boring mill is at a disadvantage as compared with the engine lathe. For boring work the outer end should be supported by a steady rest instead of the tail center. This will leave the end free for the use of any kind of boring tool that may be selected.

The horizontal boring machine can be used, as mentioned before, with a sweep cutter, as in a drill press. But sweep-cutter turning is necessarily confined to comparatively short lengths because of the overhang (and consequent spring) of the arm that carries the cutting tool.

With these choices of methods, decision should be made as to the one suitable for the particular work in hand. It frequently happens that the decision will depend largely on the previous experience of the men handling the job. A man accustomed to a vertical boring mill will naturally select that machine for the job; an engine-lathe man, on the other hand, will favor that machine for almost any work that it can possibly handle.

Where Judgment Counts.—There is no royal road to the selection of the best machine tool for a given piece of work. In some cases there may be two or more machines that would give satisfaction if properly handled. It is largely a matter of judgment on the part of the one who makes the decision. This may be based on actual experience with the different machines, their reputation and apparent adaptability to the work, or on prejudice for or against a machine or its maker.

No hard and fast rule can be given that will enable one to select the best machine for any given job. By giving the characteristics of the machines available, their adaptability for various kinds of work, and general suggestions as to the fields in which they have proved useful, it is believed that information may be given that will be useful in deciding on equipment that will prove satisfactory.

In the last analysis, however, proper selection rests with the man or men in charge of the work. Where opinion is backed by wide and unbiased experience, the results are certain to be satisfactory. The fee charged by a competent engineer with production experience will usually prove to be a good investment.

It is good practice first to consider the simplest machine on which the work can be done. Such machines have the advantage of requiring the minimum of skill on the part of the workmen and the least investment. Circumstances, such as the probable need for greater production in the future, may make it advisable to select a semi-automatic or even a full-automatic machine. But the simple machine should first have very careful consideration.

The kind of labor available should also be considered as part of the machine problem. For example, some work can be done equally well on a turret lathe or on a vertical boring mill. If the men are more accustomed to the turret lathe, it would probably be wise to select that type of machine.

Machine investment should also be carefully considered, since it plays an important part in the cost of manufacture. Machine overhead also enters into the cost of manufacture. This involves not only first cost but also the cost of keeping a machine in operation, including the cost of repairs and the value of production lost while repairs or adjustments are being made. It must also include the cost of fixtures, tools, and other equipment that may be necessary for its economical operation. The more simple the machine and its equipment that will do the work, the less the cost of machine overhead and the greater the likelihood of its being adaptable for other work.

In nearly all cases of duplicate machine work, much of the accuracy depends on the fixture in which the work is held. In such cases the machine tool supplies simply the power for turning the boring bar or for driving whatever kind of tool may be used. Yet in too many cases high-priced, precision-boring machines have been bought for work where accuracy was determined entirely by the fixtures in which the work was held. An unwise selection of machines makes these overhead charges against the work much higher than necessary and is uneconomical from every point of view.

Used or Secondhand Machinery.—Much misinformation and prejudice exist regarding the use of machine tools that have been used on other work—in other words, secondhand machinery. There are two reasons for abandoning machine tools: First, they are worn beyond the point where they will do satisfactory work, and second, they have been made obsolete by the production of much better machinery.

Every mechanic likes to have and work on new machinery. But he also knows that, unless a machine has become obsolete through the introduction of new designs, one that has been properly cared for can produce good work when run by a competent man. An automobile that has received good care will give satisfactory service for many years. The style of hoods may have changed and newer cars may have little conveniences that are lacking in the older ones, but the old ones still give a lot of satisfactory mileage. Just as a car becomes "used" or secondhand the minute it leaves the showroom, so does a machine tool become secondhand. Remembering this, we see the truth of the remark, "Every new machine is built on a used machine,"

and some of these used machines are older than their owners care to admit.

Much of the prejudice against used machines is due to misrepresentation as to their condition. In too many cases a coat of paint and the polishing of a few unsightly spots have constituted an "overhaul." Bearings and ways have not been put in proper condition and so are not capable of satisfactory work.

There are, however, many cases where used machines are thoroughly reconditioned before being sold. In some instances, they have been made better than when they were new by the introduction of new feed mechanisms and other improvements. In addition they have been re-aligned and are capable of excellent work. Some large and well-known concerns send their machines to be reconditioned knowing that, when properly rebuilt, they will handle much of their work in a perfectly satisfactory manner. Where the reconditioning of a machine can be done by the firm that built it, there should be no question as to its condition.

There might well be some central agency, sponsored by the government or by the National Machine Tool Builders Association, that would inspect all reconditioned machine tools by the standards already established. Machines that pass this inspection and bear a stamp of approval could be bought with the same security as to quality as the food we now eat. Assured that a machine was in good working condition, customers could know that is would perform satisfactorily within its capacity. Such machines would be well suited for work in the average repair or maintenance shop, or even in a contract shop handling general work and would possibly perform as well as a new machine and at a much lower cost.

There are only a few instances where the highly specialized machines used in mass production could be reconditioned to suit other types of manufacture. Mass-production shops require special equipment for many operations, and for operations on standard machines, it pays them to have the latest designs, giving the utmost efficiency. For the average shop, a machine that has been properly rebuilt is usually a sound investment. The saving in first cost, which also saves on machine overhead, will usually more than offset any possible increase in direct labor cost.

Some contract shops and those which manufacture in a limited way check the condition of their machines at stated intervals and keep them in first-class condition at all times. These are all *used* machines but are capable of doing very satisfactory work, as satisfactory as work done on the newer machines, which are the product of used machine tools in other shops.

Machines that cannot turn out satisfactory work have no place in any shop. Age alone is not a true index of the value of any machine.

How Flat Surfaces Are Produced.—Flat surfaces can be produced in a number of different ways. It was for work of this kind that the planer and shaper were primarily designed. In the planer the tool is held stationary and the work moves under the cutting edge. In the shaper the tool travels over the work. In modern planers the bed is made twice the length of the table so that there will be no overhang at either end. Before this was done, the weight of the table and the work on it caused deflection and resulted in imperfect work when the table ran over the end of the bed.

To some extent the shaper is subject to the same trouble. The farther a tool travels, the more overhang there is to the ram and the more deflection is possible. This is the case with the slotting machine or "slotter" as it is more commonly called, although in the smaller sizes it is now known as the "vertical shaper." For this reason, shaper work is kept as short as possible although some of the modern machines are very stiff and have but little deflection. Shapers are made with a stroke of 36 in. but are seldom used with that amount of overhang. In general they are for short-stroke work. They are very convenient, more so than planers in many cases, and have a wide use in railroad and other repair shops, as well as in shops making forging dies and similar work.

Flat surfaces are also made in grinding machines of various types as shown. In some, the edge or periphery of the wheel is used; in others the face or raised side of the wheel does the work. Grinding machines have taken a leading place in the production of true flat surfaces and are also used successfully on much rough grinding of surfaces.

A further development in this line is known as "lapping," where the work is moved over a flat plate with a fine abrasive

between the two surfaces. With the lap in good condition and an experienced mechanic, this method can produce one of the most accurate flat surfaces known.

Shopmen naturally think first of the machining methods with which they are familiar. Men who have always finished flat surfaces on a planer or shaper consider these machines first when flat surfaces are called for. Men accustomed to milling machines plan on using them instead of the planer or shaper. Each method has its advantages, depending on the work, the machines available, and the skill of the workmen.

Multiple and Single-point Tools.—Milling machines made their first bid for manufacturing preference by being able to machine wide surfaces of different contours at one pass of the cutters. Up to that time the planer had been used with a single-point tool for that purpose. Now, however, planer tools have as many cutters or cutting points as seem advisable, or the planer will pull and machine surfaces as wide as the milling machine. Some of the new planer tool heads carry 20 or more cutting tools, as will be shown. A lathe bed, for example, can have its entire top surface machined at one operation by either planing or milling.

This feature is not the only factor to be considered in selecting the method to be used. When metal is removed from one side of a casting or bar, strains are relieved that affect the shape of the whole piece. This change will probably be much the same with either planing or milling, where the whole surface is machined at once. Wholesale removal of metal puts considerable pressure on the piece being machined, much more than when the surface is machined with a single-point tool. Then, too, the action of the rotary milling cutter may leave a surface quite different from that left by the planer tool. For example, with a slowly revolving milling cutter and a fast feed, a surface made of a series of hills and hollows may be produced.

Although most long and narrow pieces such as beds for lathes or other machines are finished on planers or milling machines, flat surfaces of various kinds can be machined on the faceplate of a lathe or on the table of a vertical boring mill with a single-point tool fed across the work as it revolves. Here, too, the tool marks will be circular instead of straight, but the surface will be flat if the machine is properly aligned.

Another method of producing flat surfaces is by grinding. Although grinding was formerly considered only as a finishing operation and is still used in that way, some surface-grinding machines are now direct competitors of the tool-carrying machines. These heavy-duty grinding machines are made with both horizontal and vertical spindles. The vertical-spindle machines use a cup wheel, or ring type, frequently made in segments which are easily replaced. Several types of surface-grinding machines are shown in Chap. VII.

Marks Left by Tools.—A vertical-spindle machine leaves a series of circular arcs on the surface of the work, representing the diameter of the cutter being used, in contrast with the straight cutter marks left by the horizontal-spindle machine. Those who are accustomed to the planer and the horizontal machine sometimes object to the appearance of the work done on a vertical machine owing to these circular marks. This is not a valid objection and vertical-spindle machines have real advantages in many kinds of work.

This of course refers to machines in milling flat surfaces on top of the work, using the ends of the teeth. Where the cutter in a vertical-spindle machine cuts on its side, or circumference, as in milling the side of a piece of work, the feed marks will be straight the same as on a horizontal machine. They may also have wavy tendencies if the feed is too fast.

Although most long and narrow pieces, such as beds for lathes or milling machine tables, are finished on planers or milling machines, flat surfaces of various kinds can be machined in an engine lathe, either on the face plate or when held in a chuck. Similar surfaces can also be machined on a vertical turret lathe or boring mill. In both, the tool marks will be circular, but they will be concentric instead of being run together in a sort of pattern. Flat surfaces can be secured in this way. The accuracy depends on the squareness of the tool-carrying slide with the spindle that rotates the work.

Selecting Tools. *Cutting Tools.*—The selection of cutting tools for machine work is as important as the selection of the machines themselves and depends on the machines in which they are to be used. Carbide cutters have several advantages, namely, cutting speed, ability to cut hard materials, and long life between grinds. Unless the machine can be run at the high

speeds of which the cutters are capable, the advantage of cutting speed is lost.

It frequently happens that the use of carbide tools pays in the time saved by the longer life between grinds. This is particularly true where the machine stands idle during the time of grinding and replacing the cutter. Even where duplicate cutters are provided, the time of changing them may seriously reduce the daily output of the machine. Where hard spots in castings or forgings are likely to be encountered, the use of carbide cutters is sure to pay for their extra cost, because a regular cutter might be ruined. Even the time of regrinding counts heavily in some circumstances.

In a similar way, high-speed steels permit the taking of very heavy cuts in many cases. They also operate at higher speeds than carbon tools. Unless the machine in which the tools are to be used can give the increased speeds and has rigidity enough to stand the heavy cuts, its use is not justified.

As the machines themselves are frequently the limiting factor in production, all these items should be carefully considered in selecting tools for machines of any kind. Whenever a cutting material proves satisfactory, it may be advisable to standardize on it. This makes it easier for toolmakers and heat-treaters to become accustomed to it, and more uniform results may be expected.

Standardizing on cutting tools also helps in handling work on different machines. As a rule, carbide tools are used with light cuts and high cutting speeds. High-speed steel, on the other hand, can handle deep, hogging cuts but at a slower speed. Although new methods and tools should always receive due consideration, constant experimenting with new materials may easily upset manufacturing routine and only spend money instead of saving it.

Machine Tools and Similar Spindles.—With few exceptions spindles for machine tools and shafts for other mechanisms are now made from steel bars or steel forgings. Many of these are of some of the alloy steels that have such remarkable properties of strength in various directions.

Many do not seem to know that very successful lathe spindles have been made of cast iron, especially those hollow spindles of large diameter for gun lathe and similar work. Some very

successful pulley-turning lathes made in New England had very large cast-iron spindles in which the bearings were almost as large as the pulleys being turned. This, however, was before the days of carbide tools when the cutting speed was much lower than at present. It is quite possible that present-day cutting speeds might impose too great surface speed on bearings of that diameter.

Centrifugal steel casting, as made by Ford and others, has made possible different spindles and other parts of machinery of various kinds. With steel castings of the quality now obtainable, the spindle and the main gears can be cast together. The quality of these castings can be judged from the hundreds of thousands of cast-steel crankshafts that are now running in the various makes of automobiles built by Ford. Many other parts of machines can doubtless be made of this material rather than from forgings.

Machine spindles can also be made from steel tubing and have the main gears welded in place, either with or without shrinking them in place. Either of these methods can give perfectly satisfactory spindles. They can be hardened wherever it is thought desirable by the induction method. This can be done locally so that parts to be machined can be left soft if desired. The induction hardening is rapid and can be done with little or no distortion. The combination makes possible the manufacture of spindles that should be highly desirable in many types of machinery.

The use of castings or of tubing saves a large amount of machining and eliminates great waste of material in boring and turning forgings.

Combination Machines and Attachments.—Combination machine tools have never met with much favor, and their use has been confined largely to amateur shops. Machine attachments, however, have a distinct place in the small shop and even in the average maintenance or contract shop.

Attachments may best be divided into classes depending on the machine for which they are intended. Engine lathes use grinding heads, frequently called "tool-post grinders," and milling attachments. These replace the milling machine only in shops requiring an occasional milling job such as fluting a tap or reamer or some special job when a milling machine is not

available. The grinding head has many uses, among them being the finishing of work that has been turned or bored.

A variety of chucks and special faceplates aid greatly in locating and holding work in the lathe. There are also chucks and other holding devices for milling-machine work which contribute to the usefulness of this type of machine. In addition to the dividing heads for cutting gears, fluting drills, reamers, or taps, there are angle plates with graduated movement in both directions so that compound angles can be easily secured. Rotating work tables, both flat and vertical, have their places in many kinds of work.

Vises are a species of chuck, and special designs made with a swiveling base and tilting tops aid greatly in drilling holes at any desired angle or milling at the same variety of angles. Graduations make it easy to set these vises at just the angle desired.

Uses of Attachments.—Many good mechanics have devised ingenious and effective attachments to be used on various machine tools to enable them to perform operations for which the machine was not originally intended. These devices have made it possible to produce work that would otherwise have had to be sent elsewhere. Some of these attachments now on the market are for use by others who lack either the ingenuity or facilities for making them. Properly used, they can prove effective aids in increasing output and income by making it possible to handle work that could not be done on regular equipment in a shop.

Grinding attachments are available by which good internal, external, or thread grinding can be done on any engine lathe. Some of these attachments are well made, by concerns of high reputation, and will do excellent work within their capacity, if the lathe itself is in good condition. Such attachments enable work to be done that would otherwise have to be turned away or sent to other shops. The use of lathes under these conditions is advisable only where regular grinding machines are not available or where the quantity does not warrant the purchase of the proper machines, should they be available.

Milling attachments are also available for use on engine lathes and can be used in making special reamers, taps, milling cutters, and similar tools. There are also other jobs that can

be handled effectively when no regular machine is available. Turret tool posts for lathe carriages and tailstock turrets to hold drills and reamers are also available and have their place, especially in small shops and where the work does not warrant the standard machines designed for such work.

Small-job or experimental shops find such attachments useful at more or less frequent intervals. Wherever available, regular machines are always to be preferred both because of greater capacity for work and because the use of an attachment prevents the lathe from being used on work for which it was designed. On the other hand, it is sometimes possible to use these attachments on a lathe that is seldom needed for turning, while it would not pay to buy a regular grinder or milling machine and let it stand idle much of the time.

Determining the effective use of attachments or of more or less special machines, is a very important factor of management.

Right- and Left-handed Machines.—Discussions and arguments as to the advantages of right- and left-handed machine tools frequently attract much more attention than the importance of the subject deserves. In fact, the terms themselves are by no means clear to all, nor are they universally understood.

All lathes, for example, have the headstock at the left of the operator. Yet engine lathe tools that cut toward the headstock, or to the *left*, are called "right-hand" tools. This term is so much a part of machine-shop language and practice that toolmakers and engineering standardization committees have had to give up the idea of changing it.

In a similar manner, discussions and claims as to the best location for the spindle head of a horizontal boring machine are largely a waste of time. The pioneer machines of this type followed the practice of the lathe builder in putting the head at the left. Hundreds of these machines have been, and are being, used efficiently by both right- and left-handed mechanics. Others have reversed this practice and put the spindle head at the right. How far this change was influenced by the desire for novelty, only the designers know.

Machines of both types are being used in many shops. Good operators use both kinds to advantage. Preference as to the location of the head depends largely on the experience of the individual operator and possibly on whether he is right- or

left-handed. Claims for great superiority for either design will be largely discounted by thoughtful users. An established reputation for accuracy and fair dealing is much more important than the location of the spindle head.

Selecting Materials.—One of the most important problems in machine designing and in the specifications to be followed is the selection of the material to be used. This becomes increasingly difficult with the appearance of new alloys and the advances made in metallurgical research. For, whereas we now have many more materials from which to choose, we also have more opportunities to select the wrong one as well as to choose the best.

Sixty or seventy years ago there was the choice of plain iron or malleable iron castings, wrought iron, machine steel, or carbon tool steel in the ferrous group. Steel castings were available but very unreliable as blow holes were very common. Now we have much better iron castings, steel castings that rival forgings, steels of many grades with alloys that give strength and toughness undreamed of previously. We now have nonferrous alloys that replace steel in some places. We have plastics in many forms and with widely varying properties as to strength, resistance to oils, moisture, brittleness, and other characteristics.

Another factor that affects the selection of materials is the growth of welding. Coupled with this is the selection of the best method of welding, which now includes gas or flame welding, arc welding, resistance or flash welding, and the combinations that include the use of hydrogen and helium gases in special cases. Welding has made possible, and also advisable in many cases, the use of plate steel in many structures such as beds for machine tools, frames for huge turbines, and other large mechanisms. One reason for this is that the great expense of making patterns is avoided. Pattern storage is also eliminated in cases where the bare possibility of a repeat order has to be considered.

Welded structures are usually lighter than castings. This is not always an advantage, because weight is sometimes useful in securing stability and absorbing vibrations. There are cases where it may be better to make a welded structure and fill it with concrete than to make a heavy casting. All such combinations should be carefully considered from various angles before the best method is decided upon.

Before deciding on the use of welded structures of any kind, it is advisable to consult an engineer who understands the welding of different materials and who has had experience with them in structures of various kinds. No general information takes the place of specific knowledge in cases of this kind.

Anyone who has to choose the kind of metal to use for various purposes and who should know something of the characteristics of those metals should have a copy of Brady's *Materials Handbook*. This gives a large amount of very useful information about the different materials that enter into machine building and will save much valuable time in making the preliminary selections.

Effect of Materials on Machining Costs.—Economical manufacturing depends largely on the selection of the best material for the work to be done. In many cases the best material may not be obtainable or the manufacturing facilities at hand may not be adapted to handling that material. Design, as well as material, greatly affects the method of manufacture. Parts that were formerly made from castings or forgings can often be made from sheet-metal stampings at a saving of both weight and cost. There are also cases where a combination of stampings and castings or forgings, possibly united by welding, makes an ideal material.

If, however, manufacturing facilities can handle the castings or forgings but not the stampings, it may be better to use them in spite of weight and cost. Before deciding that a job cannot be done or that it may be necessary to invest in new machinery, the advantages and disadvantages of each design should be given careful consideration.

Nor is this the only problem. Whether the piece is to be made from castings, forgings, or stampings, the machinery and tooling should have careful consideration. It is quite probable that there is a new method of tooling that will greatly facilitate production.

It is often helpful to forget how work of this kind was done before and attack it as a new problem. This is particularly true in the case of sheet-metal work. The airplane industry has developed new press tools and methods by which comparatively few pieces can be made economically in the press. These

are cases where the usual types of punches and dies would be so expensive that it might be cheaper to make by hand the few pieces required.

The choice of materials is becoming more complicated every year. New materials and improvements in the older ones, as well as new uses for the ones with which we are already familiar, add to the problem. Plastics, for example, are changing rapidly and new ones with special characteristics are being produced. A striking example is the use of plastics as a body for milling cutters of small and moderate sizes. These have been developed for use on aluminum and other soft metals rather than to replace steel for heavy milling operations.

Plastics have also come into use for making forming dies for aluminum and magnesium sheets. Wood is also used to some extent for this purpose when only a few parts are needed. The softer metals such as zinc, babbitt, and particularly the low-melting-point metals known as Cerro-Matrix, Cerro-Bend, and Kirksite are widely used in forming parts of airplane surfaces, such as the skins of wings, ailerons, and fuselage. These metals can be cast in plaster molds, used as long as necessary or advisable, remelted, and used again. Some of them melt in boiling water.

Plastics do not take the place of steel dies for long runs or of sheet steel. But they have proved very useful in airplane production both because of low first cost and because they can be produced very quickly. For small-quantity production they should not be overlooked as a possibility. The Consolidated Aircraft Company has developed a plastic known as Toolite which they are using in the frames and bases of small machine tools such as bench drills.

CHAPTER III

MAKING HOLES

The making of holes in solid metal or other material begins with either a drill or a trepanning tool. Drills for solid metal may be either twist or flat, the twist having helical flutes that assist the chips out of the hole. A trepanning tool is a hollow cutter, such as a tube with teeth cut in the end, as will be shown later. This removes a solid piece of metal instead of chips. It is generally used only where the hole is larger than the usual drill, that is over 3 in., although larger drills are made.

Another method of producing a large hole is first to drill a small hole as a guide and use a sweep cutter. Some consider this trepanning also. This method will also be shown. Here the pilot fits the small hole drilled in the proper location and guides the sweep cutter while it is cutting out the larger hole. This acts as a single-tooth trepanning tool. It is also sometimes made with two teeth.

Where real accuracy is desired, neither drilling, trepanning, nor the sweep cutter can be depended on to give the desired results. These tools merely prepare the way for reaming, boring, or grinding.

Drills usually cut a hole somewhat larger than the drill itself. This is because even a slight variation in the grinding of the drill point throws the drill off center and makes it cut larger than its own diameter. This is particularly true in drilling cast iron, steel, and other hard materials.

Some materials, such as some of the plastics, seem to spring away from the drill during the cutting and close in after it has been withdrawn. This is also true of some metals. Sometimes using a slightly larger drill or grinding the drill point slightly off center gives the desired results.

When hole diameters must be made to accurate dimensions, they are usually finished by reaming, boring, or grinding. A reamer is not intended to remove much metal, only to bring

the hole to the desired size In many cases the reamer removes only a few thousandths of an inch from the drilled or bored hole Even here the reamer does not always leave the hole the desired size The condition of the reamer teeth, the material, and even the kind of of lubricant used all affect the final results, where real accuracy is necessary.

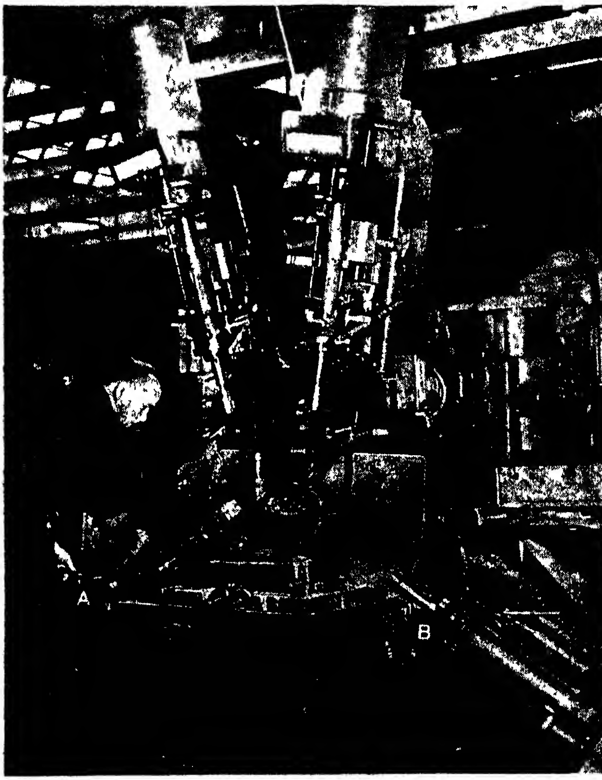


FIG. 1.—A multispindle drill made from single ones.

Either single-point boring, sometimes called "diamond boring" (because diamonds were, and sometimes still are, used), or grinding gives the really fine dimensions that are frequently required.

Drilling Machines.—There are probably more types of drilling machine than of any other machine found in the shop. They range from the small power-driven portable drill to be held in the hand up to large special drills for drilling 3-in. holes

or larger in solid metal. Small motor-driven drills are frequently mounted in frames for use as small bench drills or mounted on special bases and at various angles to make special machines for drilling several holes at once.

During the war effort, when it was hard to get special machines built, many shops took regular drilling machines and laid them on their sides, or at any desired angle, to drill holes economically.

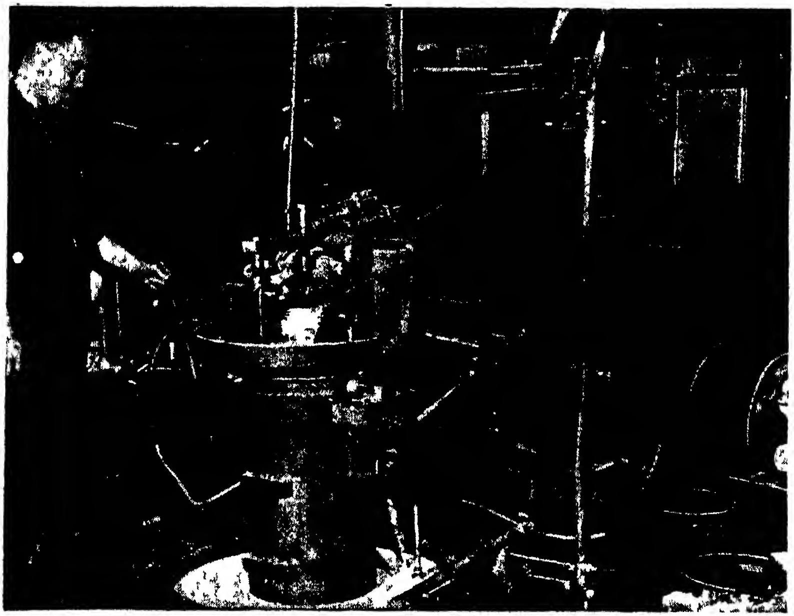


Fig 2.—Horizontal drill made from a vertical drill.

Drilling machines were also converted into milling machines to handle special work. An example of this is seen in Chap. VI.

Figures 1 to 3 show how the Continental Motors Co. converted several old drilling machines in the early days of the war to get into production on airplane engines needed for tanks and other war equipment. Figure 1 shows how two drilling machine columns were taken off their bases and mounted on new bases at the angles shown at the top. Holes were drilled for the valve guides through the fixture shown over the cylinder head. Two other drill columns were mounted as at *A* and *B* to drill other holes through suitable bushings in the sides of the fixture.

Figure 2 shows a machine built from two of these drilling machine columns mounted horizontally on a special base. Here two of the side holes are drilled, using suitable fixtures to secure interchangeability. A single column, mounted horizontally as in Fig. 3, drills a deep hole in the end cover casting shown. This fixture can be indexed around so as to handle several holes around the edge of the cover.

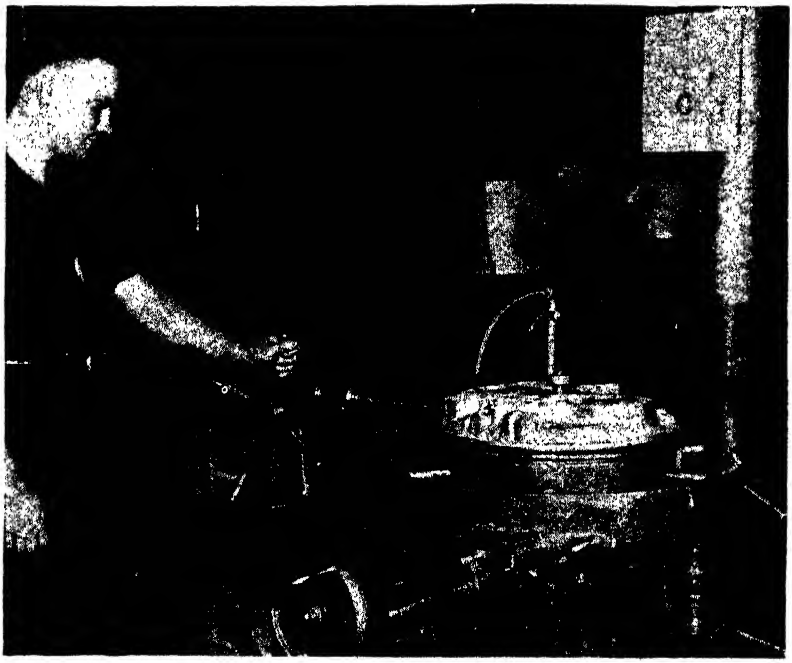


FIG. 3.—Drilling a deep hole on a rebuilt machine.

Building Special Machines from Standard Units.—Where manufacturing operations require the use of several tools at once, as in multiple drilling, it is frequently possible to construct such a machine by combining several standard units in the proper positions. Although this has been done many times in the past, the demand for special drilling and other machines for the war effort developed much latent ability on the part of shopmen and tool designers.

Special drilling heads with horizontal spindles have been a regular product for some years and have been combined in various

ways. But shops making war materials have gone a step further. One such example is seen in Fig. 4, where seven inexpensive drilling machines designed for bench use have been utilized in building a special machine. Here the drilling machines have been tipped over on their backs, with their columns in a horizontal position, and arranged at the desired intervals around a central base casting.

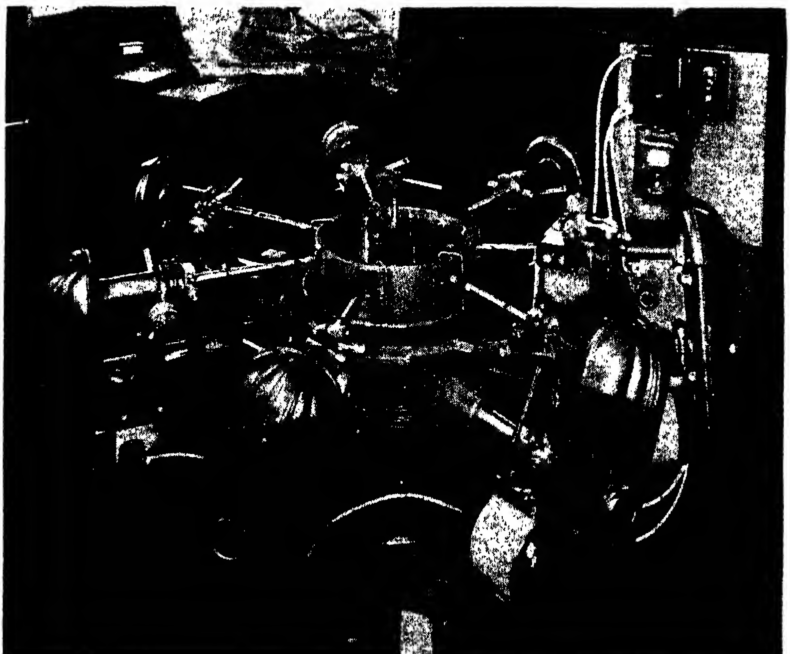


FIG. 4.—A multispindle machine made by mounting seven small drills horizontally on a central base.

With their own base castings removed, they were bolted to suitable pads on the central base casting at the proper angles. In the center of the base is a table to hold the work and to support the drill bushings as close to the work as possible. Quick-acting clamps make it easy to load and unload the fixture. All the drilling heads are supplied with independent motors, and all are wired together so that a single control handles all seven machines. The machine shown was built at the Jacobs Aircraft Engine Co. for use in their war work.

Other Drilling Operations.—Another adaptation of a drilling machine to special work is seen in Fig. 5. Here the column of the machine has been raised to give additional height for the tapping device on the lower end of the spindle. A guide plate in the center locates the device centrally with the cylinder holes

FIG. 5.—The column of this machine has been raised to suit the work.

in the crankcase while the tapping spindles are at work. These spindles are driven by gearing suitable both to rotation and to speed. The springs on the central shaft counterbalance the weight of the tapping head so as not to affect the lead of the taps as they enter the work.

A simple form of radial drilling machine is seen in Fig. 6. This is an old design with belt drive put to use in the war effort. This type of drill has decided advantages on many kinds of work.

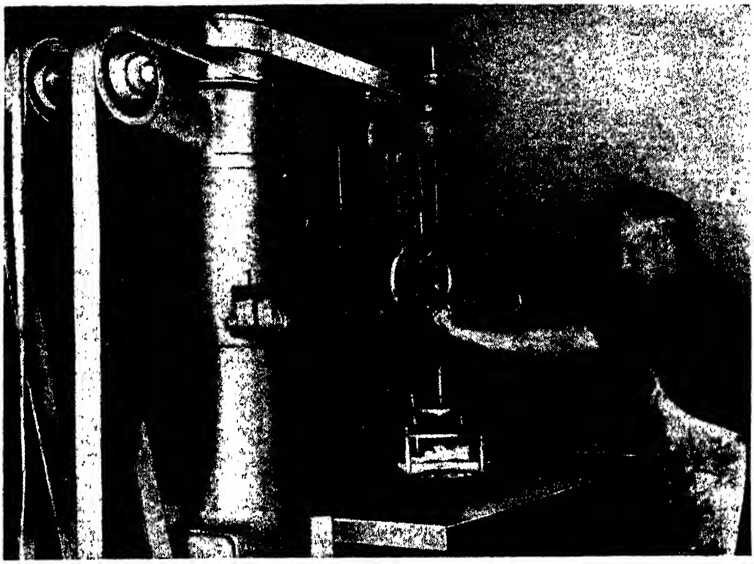


FIG. 6.—An old style belt-driven radial drill used in war work.

FIG. 7.—Using two large radial drills on a marine-engine bed.

The drilling spindle can be moved over a wide range as the drill can not only be swung through a wide arc but can also be moved at various points along the arm The advantages of this can be seen in Figs. 7 and 8.

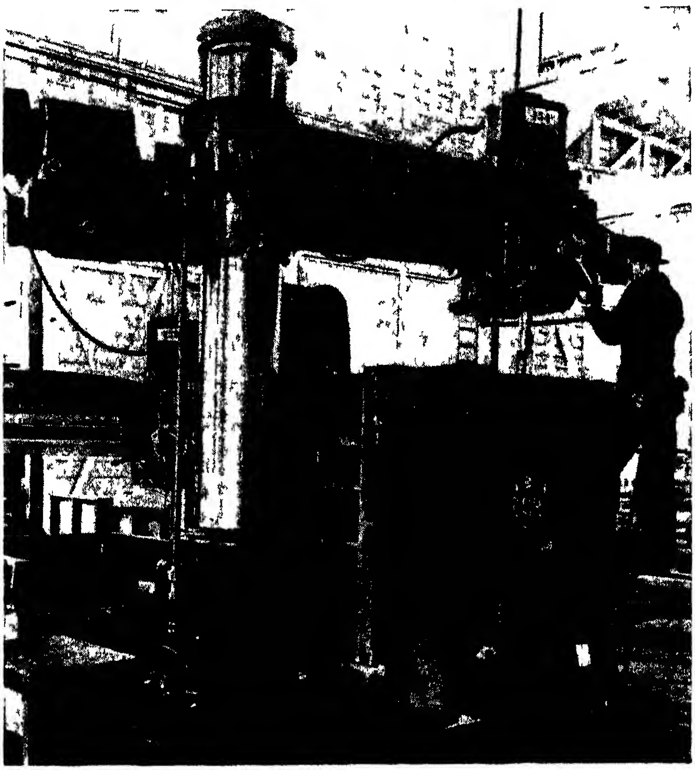


FIG. 8 —An extra high column on a radial drill can be avoided by using a pit

Radial Drills at Work.—The work being done in Fig. 7 shows an unusual arrangement of radial drilling equipment used at the Joshua Hendy Iron Works in machining a large marine engine bed section. Extensive use is made here of big radials, and two machines of 7-ft. and 8-ft. capacity are shown being used simultaneously on the bed casting. The radials handle drilling, tapping, facing, and other operations, not only on engine beds but also on cylinder flanges and other parts.

The engine bed section shown is mounted on a four-wheel car on tracks, which, when the work is in position, is supported on

jacks properly placed for leveling and stabilizing the work. The radial drill at the right is an 8-ft. machine; the one at the left is a 7-ft. arm radial.

In handling such large work much time and effort are saved by the proper placing of heavy tools so that uneconomical shifting of big castings and the like is reduced to a minimum. The example just referred to is a case in point. This is one of several

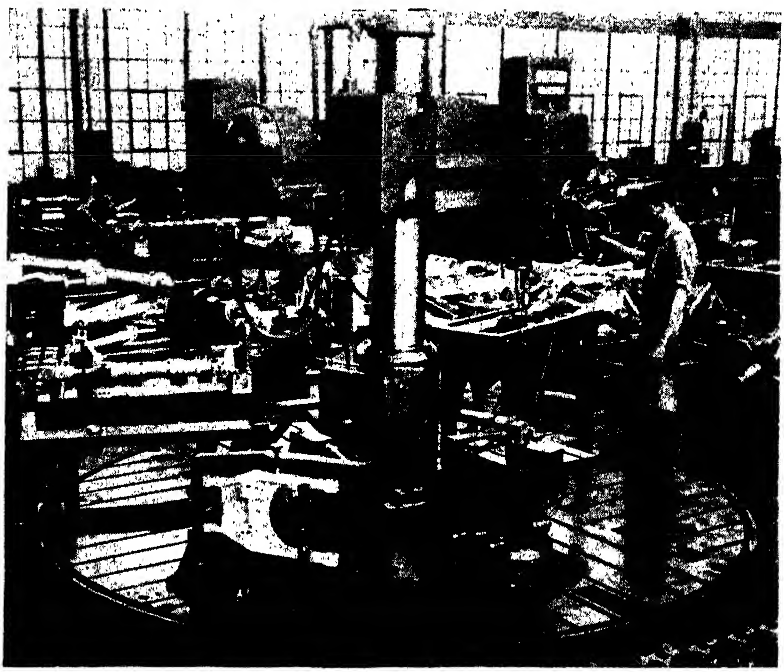


FIG. 9.—With the radial drill in the center of a circular table, work can be set up at various points and the drill kept at work with little loss of time.

groups of heavy tools so placed as to take care of the greater part of their work with little loss of time and labor.

The desirability of a floor pit for certain big castings is brought out in Fig. 8. The radial drill in the foreground is shown operating on stud holes at the top of the tall cylinder casting. At the rear and to the left is seen the top of another casting, located in a pit so that the work can be drilled and tapped with the radial arm and spindle in lowered position within easy reach of the operator. This enables normal sizes of radials to handle big jobs without exceeding the height capacity of the machine.

Using Radial Drills to Advantage.—The advantages of radial drilling machines for a large variety of work is not always understood. As with any other machine tool, its value is materially increased by keeping its spindle busy. In other words, idle time reduces the value of the machine and adds to

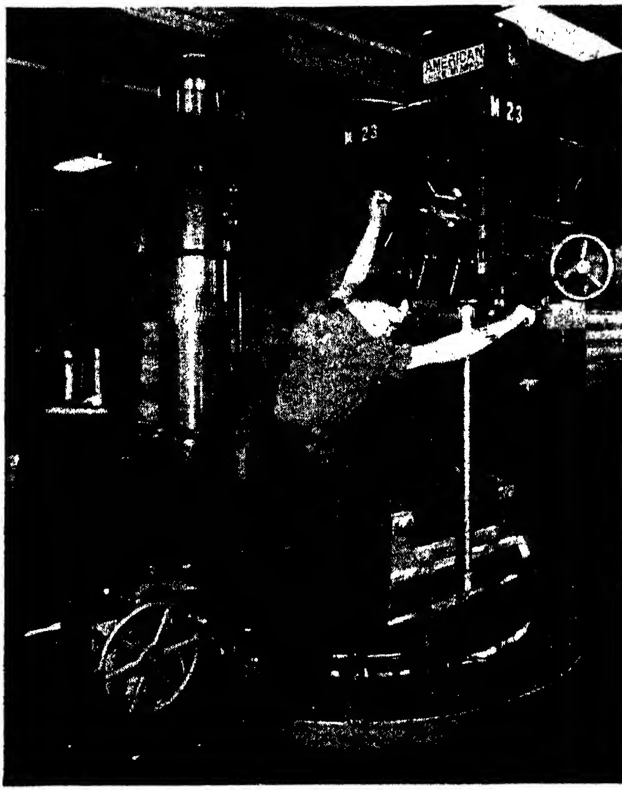


Fig. 10.—Drilling a gun mount in a special fixture.

the overhead by decreasing its earning capacity. Any method of reducing this idle time increases the value of the machine.

The illustrations that follow show some of the ingenious ways in which idle time has been reduced to a minimum in a number of shops. In Fig. 9, for example, the American radial drill column is mounted in the center of a large circular table which carries several fixtures holding work to be drilled. Instead of letting the machine stand idle while the work is changed in a single

fixture, these are operated by two men so that the drill operator can simply swing the arm from one job to the next while the second man is taking out the finished work and replacing it with a new piece. Quick-change drill chucks and special attention to tooling further reduce lost time. This illustration shows a variety of jobs being done on the one machine.

FIG. 11.—This gun mount is tilted to make the holes in various planes accessible.

An entirely different but equally interesting use of special fixtures is illustrated in Figs. 10 and 11. These show the drilling of a gun mount in the shops of the Link-Belt Ordnance Co. and how time is saved by the use of a complete fixture which not only locates the gun mount but also positions it in different ways so that the holes in the various surfaces can be reached.

The extended drill spindle in Fig. 10 enables the operator to reach the lower flange of the work with the radial arm at normal

height for drilling most of the other holes. It will be noted that this extension is in three parts so that various heights can be reached with the same position of the arm.

In Fig. 11 the extensions have been removed and the fixture tilted so as to reach one of the angular surfaces. This also

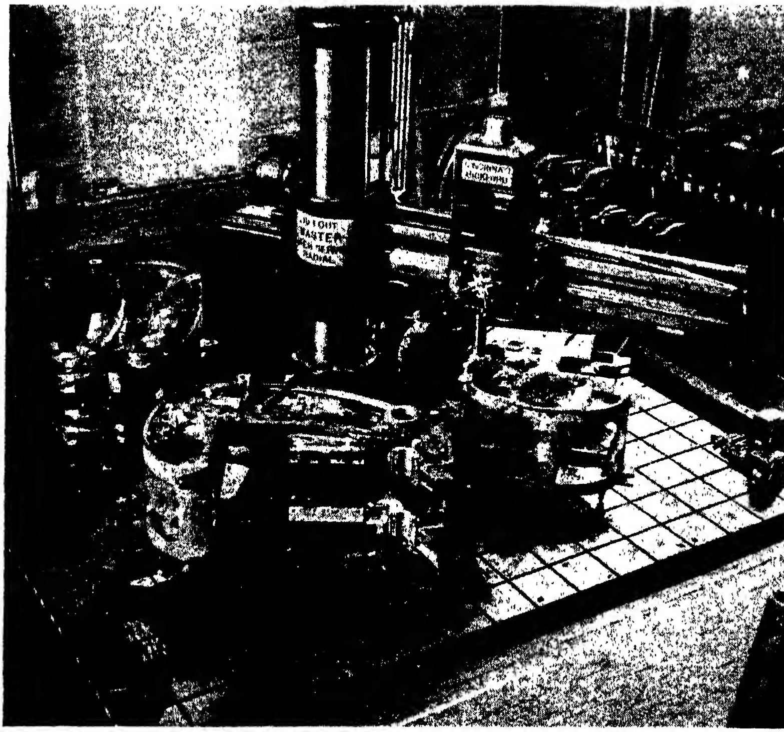


FIG. 12.—Punch-press frames being drilled on a large square table or floor plate.

shows a jig plate bolted to the gun mount near the right-hand trunnion and the clamping mechanism at the trunnion itself. This view also shows the ingenious manner in which this gun mount is built up by welding, with stiffening ribs on the outside and the angular steps welded in position. These excellent illustrations are available through the courtesy of the American Tool Works.

Equally interesting adaptations of the radial drill are shown in Fig. 12 supplied by the Cincinnati-Bickford Tool Co. Instead of a round table, Fig. 12 shows a square table in the shop of

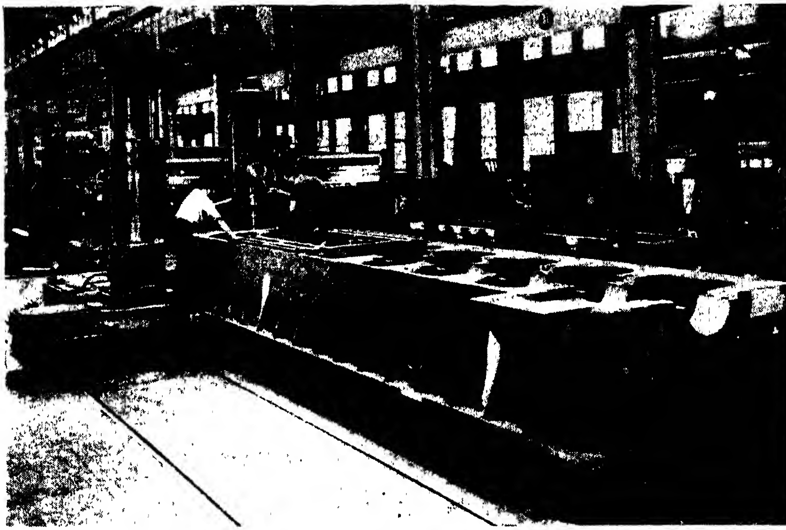


FIG. 13.—A radial drill mounted on tracks and a truck in order to reach the points on a long engine bed.

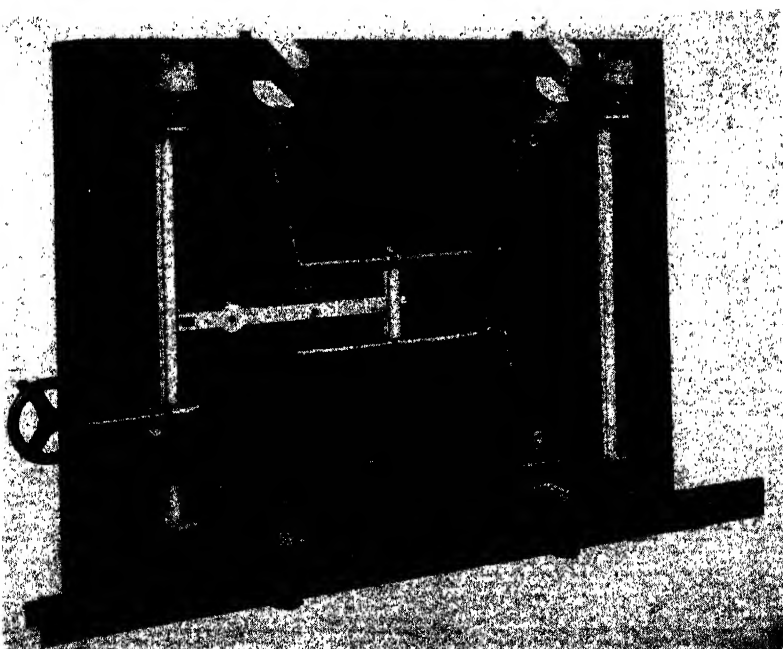


FIG. 14.—Method of clamping a truck to rails.

the Niagara Machine & Tool Works on production of their press frames. Here four frames are grouped around the central column of the machine so that the various parts to be machined can be reached with a minimum of adjustment of the spindle on the radial arm. Here too the work is set up by other men

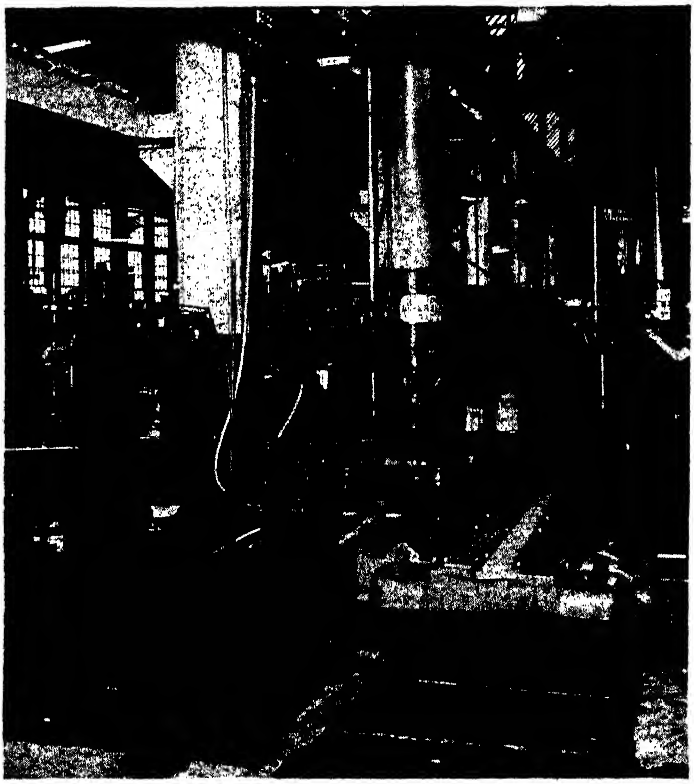


FIG. 15.—Here the column of a radial drill is mounted on a carriage that moves along a machined bed. This permits the accurate location of holes with little loss of time.

so that the machine operator can keep the radial at work with practically no delay.

In Fig. 13 the radial drill is mounted on a special truck to run on a track beside the huge bed of a large diesel engine. This carriage enables the machine to be run to any desired position beside the bed and holes drilled at any point. The method of locking this truck to the rails is shown in Fig. 14. As shown, the

lower clamps are locked to the rail, which is omitted from the upper clamps in order to show their action. A 40-deg. movement unlocks the clamps and permits them to be lifted from the rails. Both the moving of the track base and the clamping can be done either by hand or with small motors, as desired.

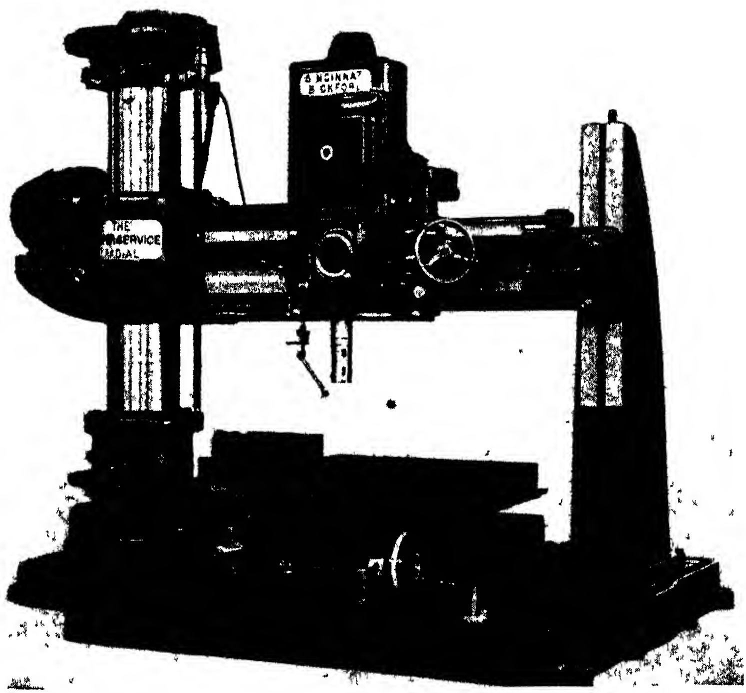


FIG. 16.- Universal adaptation of radial drill for jig and fixture type of work

Similar results are secured, and with greater accuracy, by mounting the base of the radial on a suitable bedplate, as in Fig. 15, which shows the drilling of a planer table in the shop of the Cincinnati Planer Co. Holes for bolting the herringbone rack to the underside of a planer table are being drilled at all points desired. This method of mounting the radial machine puts it in the class with the floor-type horizontal boring machine, the difference being largely in the position of the spindle of the machine

Another unusual adaptation of a radial drill is seen in Fig. 16 where the outer end of the arm is supported by an outer column This also resembles some applications of the horizontal boring machines and shows how various machines can overlap in their capacity for doing various kinds of work. This machine could

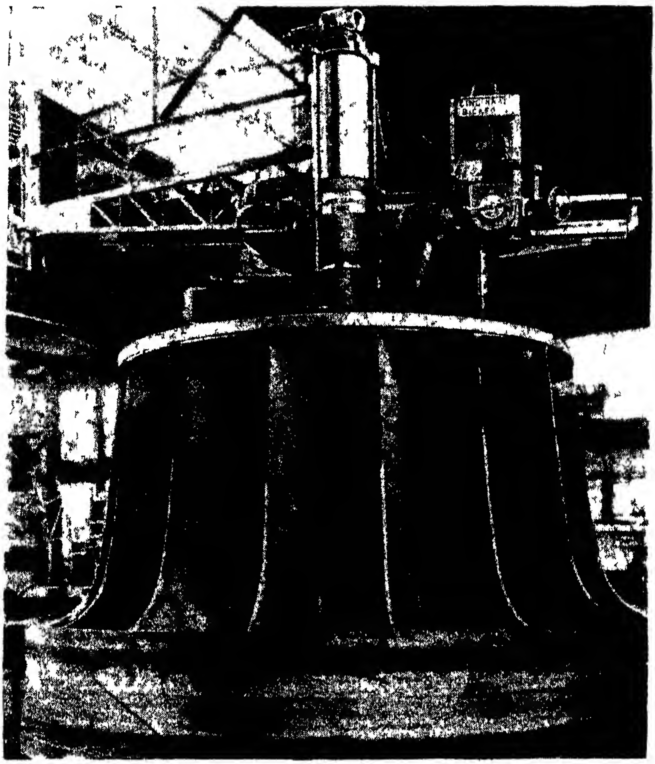


FIG. 17.—Using a radial drill on top of a large turbine runner.

be used as a vertical milling machine in the same way as is done with the horizontal boring machine, as shown in Chap. VI.

Although these radial drills are both large and heavy, they are frequently used as portable machines by being moved from place to place and even mounted on the work itself as seen in Fig. 17. A suitable connection is provided at the top of the column and the traveling crane lifts and locates the radial wherever it may be needed. In this case it is on top of a large turbine runner in the plant of the Dominion Engineering Co.,

Montreal, Canada. This is a 6 ft.–17 in. machine, which in radial drill parlance means that the arm is 6 ft. and the column is 17 in. in diameter.

Boring on the Radial Drill.—Radial drills are also frequently used in place of boring machines as shown in Fig. 18. Here

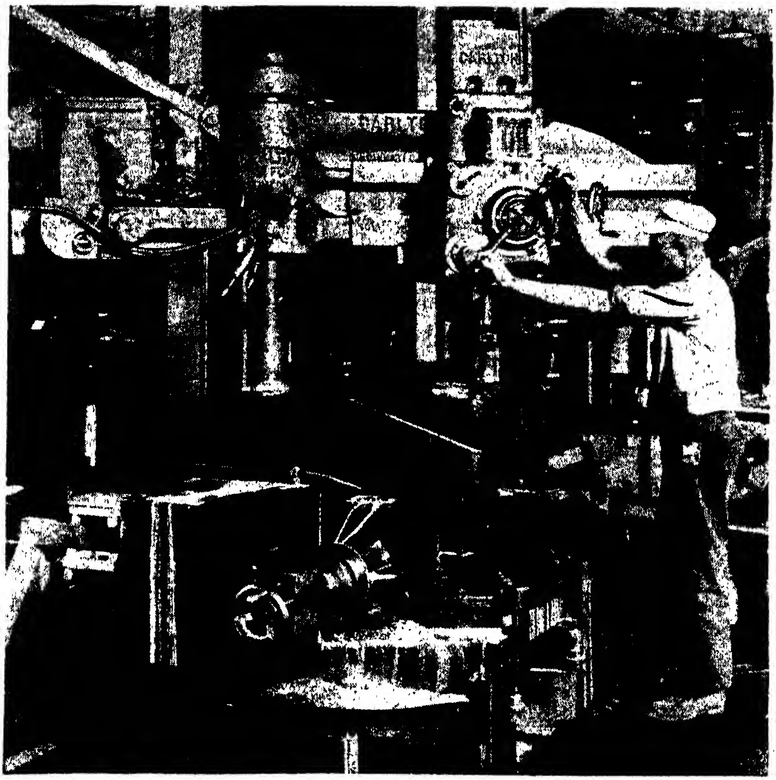


FIG. 18.—Using a radial drill as a boring machine with a fixture for securing duplicate parts.

a Carlton drill with a 4-ft. arm is acting as a vertical borer on the large piece of work shown in the fixture. The fixture locates the work by means of the trunnions at each end while the guide bushings in the substantial upper part of the fixture locate the boring tools in their proper position and guide them while they finish the holes in the work below.

This is one of the jobs that could be done on a horizontal boring machine as well as on the radial. Similar fixtures could

be used in either machine. In the situation illustrated the radial was most easily available and so was put to work on the job. The ease with which the spindle of a radial drill can be moved into any position within its range makes it particularly convenient for work of this kind.

FIG. 19.—Another drill-jig job on a radial machine.

An Unusual Drilling Job.—A somewhat unusual drilling job is shown in Fig. 19 where a drill jig is located in the recessed hole for one of the cylinders of a large diesel engine. With the drill jig centered in the cylinder opening, it is easy to swing the drill arm and move the spindle along the arm until the drill is exactly in line with the jig bushing. In this way it is possible to locate the holes along the side of the frame in correct position without having a very large fixture in which the whole frame would have to be placed. The convenience in handling as well as the

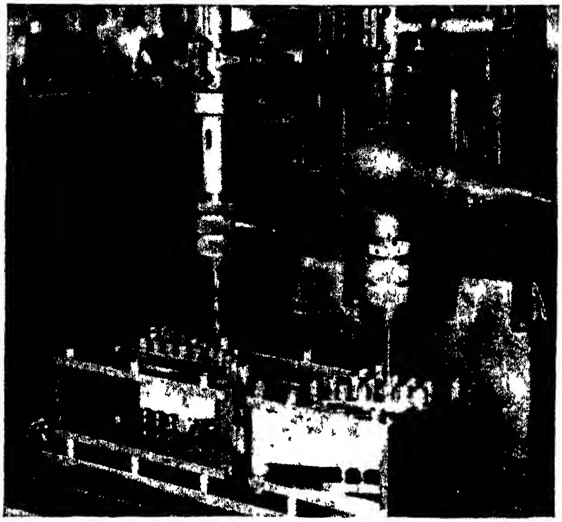


Fig 20.—Simple drill jigs of the box type.

Fig. 21.—Using a partial jig—it only covers part of the work

cost of the fixture makes this method advisable where it can be used.

Simple Drill Jigs.—Two types of simple drill jigs are seen in Figs. 20 and 21. The first shows a somewhat unusual box jig, so called because it encloses the work in a sort of box. This has numerous drill bushings to locate holes in the work inside, which is of peculiar shape, extending into both parts of the jig.

Fig. 22.—Small drill mounted on a rotating table.

This type of jig frequently has bushings on both sides and can be turned over after one side is drilled.

In Fig. 21 is seen a partial jig which must be accurately located on the work to have the holes drilled in the proper position. Such a jig ensures the holes being the correct distance apart, but their relation to the other parts of the casting depends entirely on the accuracy of the setting of the jig. The clamp rests on the rib which has been welded on, to increase the stiffness of the plate itself. Jigs of this kind are much less expensive than those which enclose the whole piece, but they require accurate

setting to give satisfactory results. It is, however, possible to design partial jigs of this type with locating points to position them accurately on the work.

Drill Mounted on a Rotary Table.—Although not a radial drill in the usual sense, Fig. 22 shows a very convenient use of a small

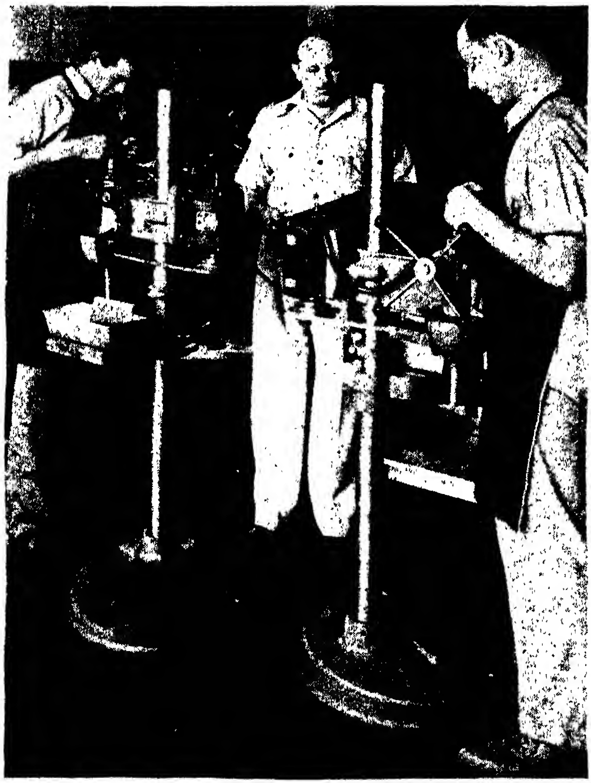


FIG. 23.—Mounting drills upside down for reaming and burring.

Delta drill on work requiring holes spaced at regular intervals around a disk or plate. The head of the small drilling machine is mounted on the central column shown which is, in turn, mounted on a sliding base so as to secure the desired radius for the rows of holes to be drilled.

As shown, the work is beneath the jig plate which guides the drill into the work. The machine can also be used without the jig plate if desired by using the indexing notches on the base

plate of the drill. Such a combination will be found useful in many shops.

Mounting Drills Upside Down.—Special uses of machines lead to ingenious methods in shops where the managers are also good mechanics or open to suggestions. The Airco Tool Co., a West Coast shop, found it advantageous to reverse the heads of some

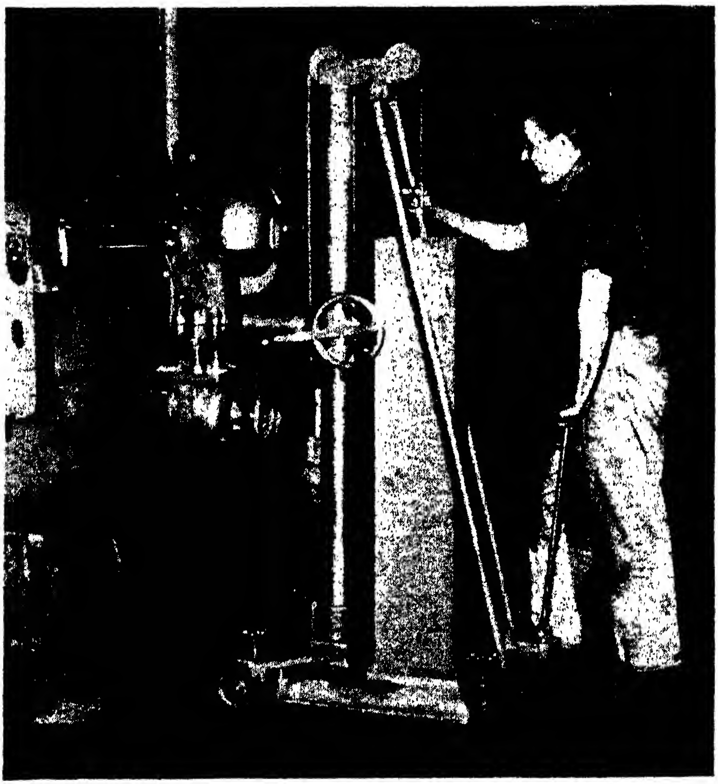


Fig. 24.—Special mounting of a drill in order to reach a side of the work.

small drilling machines, as shown in Fig. 23. They were turned upside down on their columns so that the drills pointed up instead of down. This was found very convenient in reaming small holes or in removing burrs from previously drilled holes, the work being held in the hand.

The table of the drill, instead of being used to support the work, holds pans in which the pieces are kept. It will also be noted that the base of these drills has a pad that is planed and

slotted. It is a special base so arranged that work supports can be fastened in place whenever necessary.

Taking the Machine to the Work.—Moving a large bed casting to a boring machine and locating it properly just for the drilling of a few small holes would be an expensive operation. So John Brouwer, superintendent of the Gallmeyer & Livingston Co., rebuilt a standard Buffalo No. 18 column-type drilling machine into a portable drill to handle this job. He removed

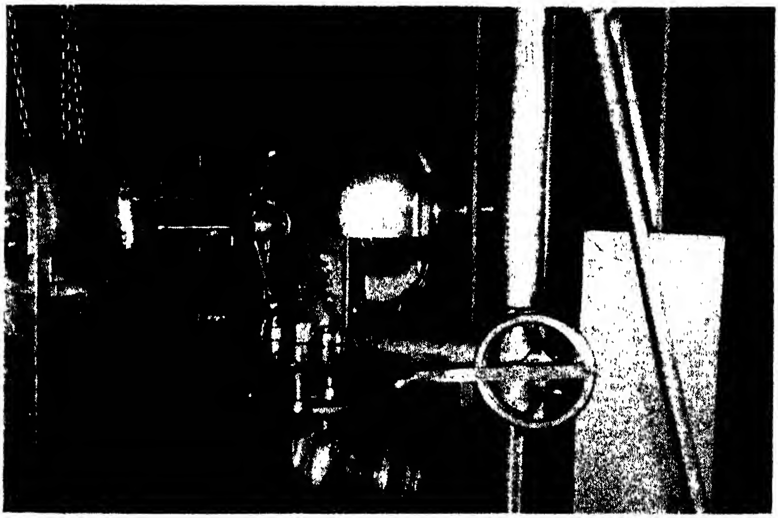


FIG. 25.—Close-up of a drill at work.

the drill head from its column and mounted it on a round support with a base at the bottom, as seen in Fig. 24. This made the drill into a horizontal machine which could be adjusted up and down on the main column and also be turned on the horizontal column if desired. A close-up of this is seen in Fig. 25.

For safety and convenience, the wheeled base of the portable machine has a rectangular box in which the counterweight slides. The base can be easily moved to the work and fastened by using the cup-ended screws against the floor to prevent movement during drilling.

The drill head is moved vertically on the main column by a rack and pinion operated by the lever extension on the handwheel. A ½-hp. motor at 1,725 r.p.m. gives power to drill holes up to 1⅛ in. in cast iron, but few holes run over 1 in.

With the machine to be drilled set up on blocks for the final scraping of the bed, the drilling machine is rolled into position and locked to the floor by the screws already mentioned, and the necessary holes are drilled. This makes a very compact device and one that can be used in a variety of work.

FIG. 26.—This job was formerly done with a power drill held by the operator. Now he simply feeds the drill into the work.

Another example in which it paid to take the machine to the work is shown in Fig. 26. Instead of setting the large lathe beds on end under a radial drill, which would have meant considerable handling and would have required a pit under the drilling machine, the Monarch Machine Tool Co. devised this drilling fixture.

The standard portable drill is mounted on a special base which fits into the large holes in the end of the lathe bed and centers the drill head. The two adjustments shown enable the operator to bring the drill to the correct radius for locating the holes drilled around the large opening in the bed. Then,

instead of supplying the necessary pressure for feeding the drill himself, the operator simply turns the feed screw at the end and the holes are easily drilled. An index plate just outside the large hole and on the base of the drilling fixture makes it easy to space the holes correctly around the large opening in the bed.

There are many cases where the use of fixtures of this kind will pay big dividends.

FIG. 27.—Using weights to give a uniform pressure on the spot-facing tools.

Using Weights for Feeding Spot-facing Tool.—In some cases, weighted feeds can be used satisfactorily not only to save manual labor but to produce a uniform pressure on the tools being used. Such a case is seen in Fig. 27, where weights on the ends of the feed levers of two sensitive drills provide constant pressure for the tool on the work, spot-facers in this case.

This was done by John D. White in the Cadillac plant to secure just the right pressure to give the finish desired on the spot-facing of the flanges being machined. This enabled him to

handle two spindles with ease and produced the finish desired. In work of this kind the keenness of the cutting edges of the tool should always be considered as it affects the pressure necessary to give the proper "bite" into the work.

Back Spot-facing.—One department of Pratt & Whitney recently ran short of regular machines for back spot-facing and

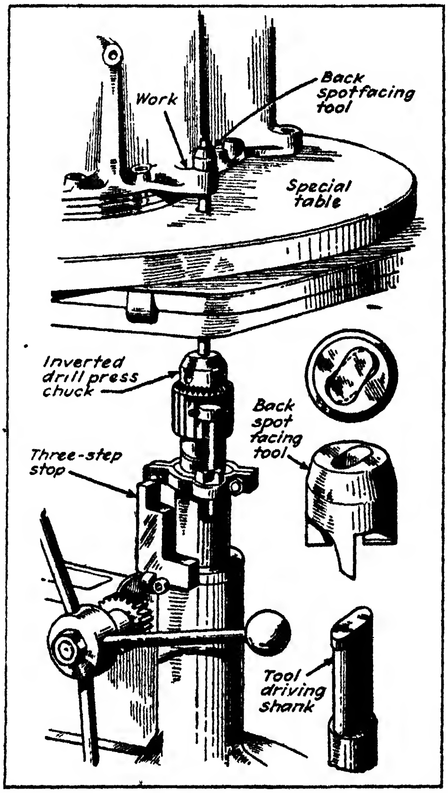


FIG. 28.—Tool and drill used in back spot-facing.

was unable to secure new ones promptly. George Waller of the production engineering department rigged a light drill press to do the same work effectively and at small expense. The machine, as made, had the drill head in an inverted position below an improvised table. The table carried a groove to center the large casting, which required back spot-facing of several holes in a bolt circle. As three different heights of bosses were to be spot-

faced, a three-step stop was pivoted for quick shifting, as shown in Fig. 28.

The tool for back spot-facing had a lozenge-shaped bore (made by drilling two holes side by side and joining them) as shown. The tool was slipped over a shank similarly shaped but slightly smaller with narrow shoulders on two sides to transmit

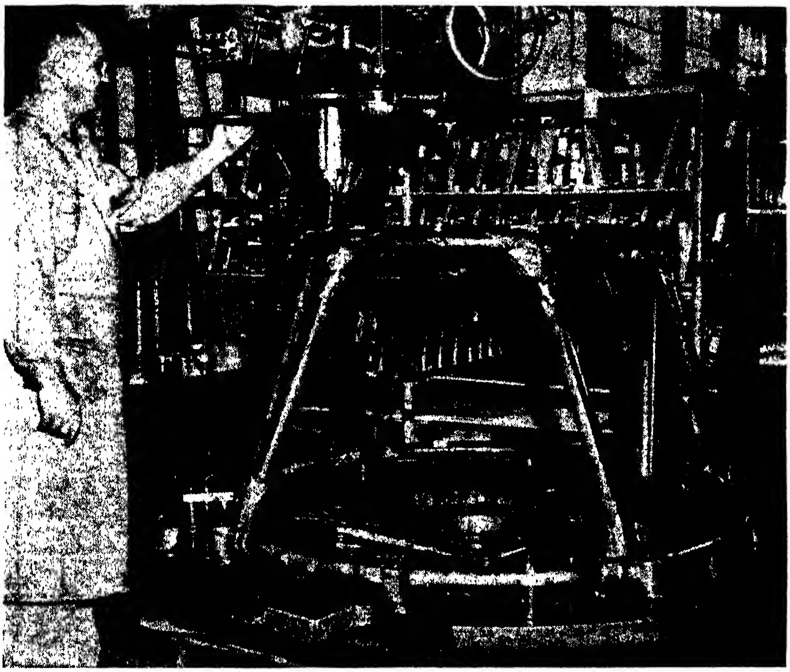


FIG. 29.—Turntable fixture for drilling airplane-engine mounts.

the downward pull of the press. When the shank drove the tool, it gripped the sides of the bore and the shoulders overhung the hole edges, but when the tool stopped, it disengaged itself from the shank so as to be easily removed. The spindle was withdrawn through the hole in the flange of the casting being machined.

A Turntable Fixture Made from an Old Flywheel.—Shopmen with a little ingenuity can usually find a way to do almost any job that comes along. One of the smaller subcontractors for aircraft parts who made engine mounts for radial engines needed a rotating fixture to drill the various holes in the mounting

circle. Raw materials were scarce, but one of his men used the discarded flywheel of a diesel engine as a basis for the fixture, as seen in Figs. 29 and 30.

The bottom piece *A* was also found in the scrap pile and both this and the flywheel *B* were grooved to act as a ball bearing, as seen. Holes drilled through the flywheel to the ball race made it easy to oil it whenever necessary, and small plugs tapped into the upper end kept the dirt and chips out. A 2-in. slab of steel was cut with a torch to the size and shape wanted and fastened to the top of the flywheel, as at *C*.

This held the engine mount as shown in Fig. 30. With this fixture mounted under a radial drill, it was easy to reach any

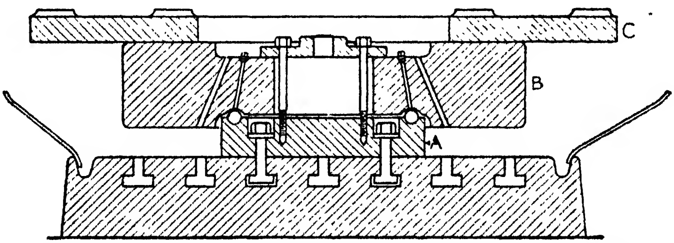


FIG. 30.—Details of the turntable made from an old diesel flywheel.

point to be drilled as the engine mount was turned on the flywheel base. The accuracy of such a fixture depends on the care with which it is made. In this case the runout was less than 0.010 in.

Improvised Drilling Machine for Marine Stern-tube Liners.—A very unusual job is seen in Fig. 31. When the Dodge Mfg. Co. contracted to make stern-tube liners for steamships, they expected to drill the ends on their regular horizontal boring machines. As all these machines were loaded with work, they improvised a machine using the bed of an old lathe to carry the work. On this they mounted carrying rests with rollers as can be seen. As a power unit, they took a standard No. 25A Ex-Cell-O drilling head with a hydraulic feed and mounted it on the cross slide shown, which was fitted to a heavy cast-iron base.

The stern tubes were placed in the rest on the rollers to permit easy turning from hole to hole. A cast-iron plate-type drill jig was fastened to the end of the stern tube to locate the two rows of eight holes each that had to be drilled through the flange.

With the jig plate in place, the cross slide was aligned to bring the drill spindle in line with the holes in the jig, the cross slide was clamped, and the first hole was drilled.

After the first hole was drilled, the tube was rotated to bring the next hole in line and so on until all holes in both circles had been completed. The outer holes had clearance for 1-in. bolts, but the inner rows were drilled 7/8 in. to be tapped for 1-in. coarse

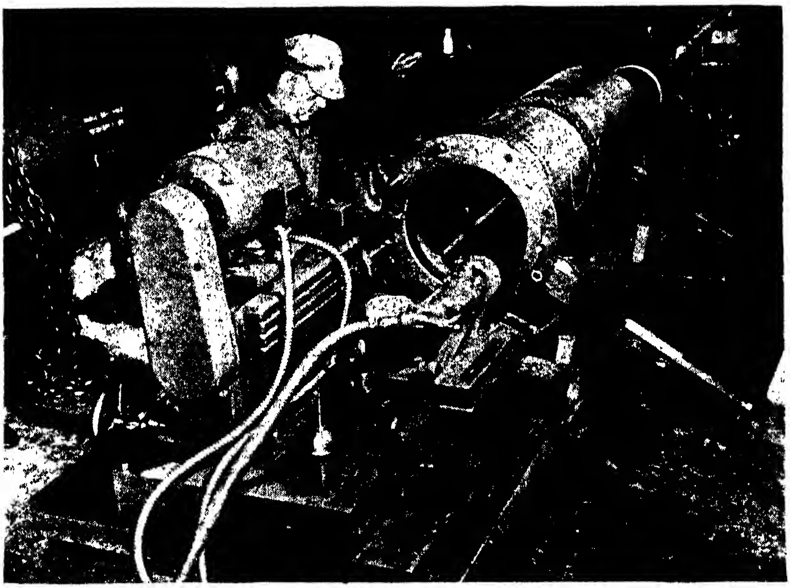


FIG. 31.—Drilling flange holes in an improvised machine.

threads. The holes were drilled at 300 r.p.m., and hydraulic feed was used.

For tapping the holes, an Ingersoll-Rand nut-setting motor was mounted as shown at the bottom of the liner. This has a movable base which permits the tap to be fed into the hole as it revolves. Tapping is of course done after all the holes are drilled and the jig plate is removed. This device proved very satisfactory for work that would ordinarily have been done on a horizontal boring machine.

Drilling Brake Linings.—In Fig. 32 one of the low-cost bench drilling machines has been rigged to drill and counterbore aircraft brake linings. The linings are first drilled in the jig shown at the back of the column. The linings are held in position

inside the drum and the holes located by the drill bushings shown.

Then pin *A* is removed, the fixture swung halfway around to the position shown and the holes that have been drilled are counterbored as shown at *B*. The brake lining is supported by

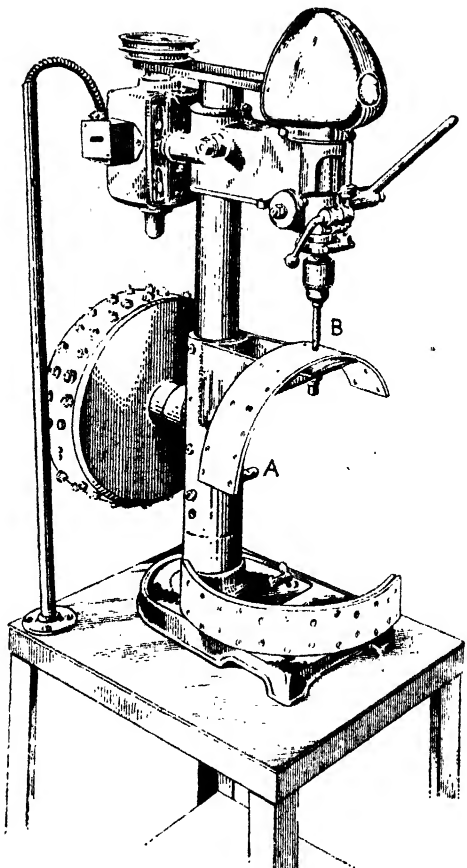


FIG. 32.—Drilling brake bands at an airplane landing field.

the curved block, and the work is indexed by hand from one hole to the next. This performs both operations on one machine and saves time in handling. It was designed and is used in one of the repair bases of the American Airlines.

Drilling Irregular Holes.—Round holes are easily drilled, but holes of irregular shapes are usually made by drilling a round

hole and then cutting away the sides until the hole has the desired shape. On holes drilled through a piece, this was often done before the days of broaching by filing and chipping. On holes that go only part way through a piece, however, it is a difficult job. Broaching now handles most irregularly shaped holes that go through a piece, but this requires the making of broaches and the use of a broaching machine. Where the quantity warrants the cost of machine and broaching tools, this is the economical method of producing irregularly shaped holes, but there are many cases where the method of making irregular holes that was devised by the Watts Brothers Tool Works, Wilmerding, Pa., is used.

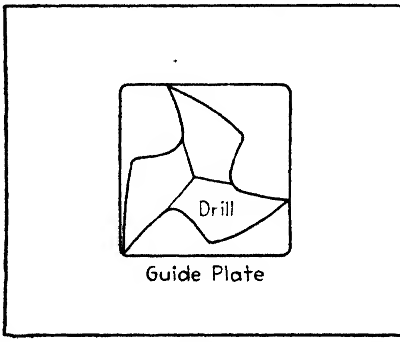


FIG. 33.—How square holes are drilled.

This method includes the use of a full-floating chuck, a guide plate, and special angular drills. Figure 33 shows how a three-lipped drill is guided in the square hole in the guide plate for cutting a square hole. These drills cut on the end, as with any drill, and the edges shown act as guides to force the cutting end to the shape wanted. These drills are primarily for blind holes but also for making dies for punching. In drilling hard metals, it is better to drill a lead hole of small size to remove the center portion of the metal. When used for blind holes, the depth should not exceed twice the diameter of the hole. These drills have a tendency to cut a trifle large (0.002 to 0.003 in.) in a $\frac{3}{4}$-in. hole. This should be remembered when holes of exact sizes are required. There is also a tendency to cut a little large at the bottom of the hole, which is frequently an advantage. Although these drills are used mostly for square or hexagonal holes, they can be used also for other shapes, such as five- or eight-sided openings.

These drills can be used in either a drill press or a lathe. They cut on the end only and should be kept sharp by careful grinding, as suggested by the makers. Their recommendations as to speeds and feeds should also be followed. Knowledge of this method may save time and money on some jobs.

Drilling Hardened Steel.—A new drill known as "Hardsteel" is now available for drilling holes in armor plate or hardened steels of any kind, even the high-speed steels. It is made from a cast alloy by the Black Drill Co., Cleveland, Ohio, and is three-cornered in shape with small hollows ground in each cutting face for chip clearance. It should not be used in soft materials, only in materials that cannot be drilled by the usual tool.

It takes five or more seconds after the drill contacts the work before it begins to cut. By that time it has built up enough frictional heat to anneal the metal in actual contact with the drill point. Then the drill begins to cut and regular chips form. Sufficient pressure should be kept on it to maintain the flow of chips. Hand feed is preferred in order to maintain a "feel" of the way the drill is cutting.

DRILLING SPEEDS (WITHOUT COOLANT)

Inches	R.p.m.
$\frac{1}{8}$	2,500–3,000
$\frac{1}{8}$ – $\frac{3}{16}$	2,000
$\frac{3}{16}$ – $\frac{1}{4}$	1,600
$\frac{1}{4}$ – $\frac{5}{16}$	1,500
$\frac{5}{16}$ – $\frac{3}{8}$	1,200
$\frac{3}{8}$ – $\frac{7}{16}$	1,000
$\frac{7}{16}$ – $\frac{1}{2}$	950
$\frac{1}{2}$ – $\frac{5}{8}$	900
$\frac{5}{8}$ – $\frac{3}{4}$	800
$\frac{5}{8}$ – $\frac{3}{4}$	750
$\frac{3}{4}$ – $\frac{7}{8}$	700
$\frac{7}{8}$ – 1	600

These drills are run at high speed, the accompanying table giving approximate speeds for the sizes shown. Should the drill fail to cut properly, a higher speed should be tried. In drilling work-hardening materials it may be advisable to increase the chip clearance groove to take out a wider chip. The chips should be cleared from the hole every $\frac{1}{8}$ in. of depth drilled. Short drills are to be preferred where they can be used. The drills can be ground by hand, and the shape of the new drill should be maintained in grinding.

Among the uses for Hardsteel drills are the drilling out of broken drills or taps, the drilling of holes that have been forgotten before hardening, and also the drilling of holes that might be distorted in hardening if drilled while the work is soft. These

are what may be called "emergency" drills but have a distinct place in many shops. They are generally used dry. If the heat generated discolors the work, water with a rust inhibitor may be used. Lubricating or cutting oils should not be used.

Removing Broken Drills with Dynamite.—Years ago some railroad shops found it necessary to force piston rods out of

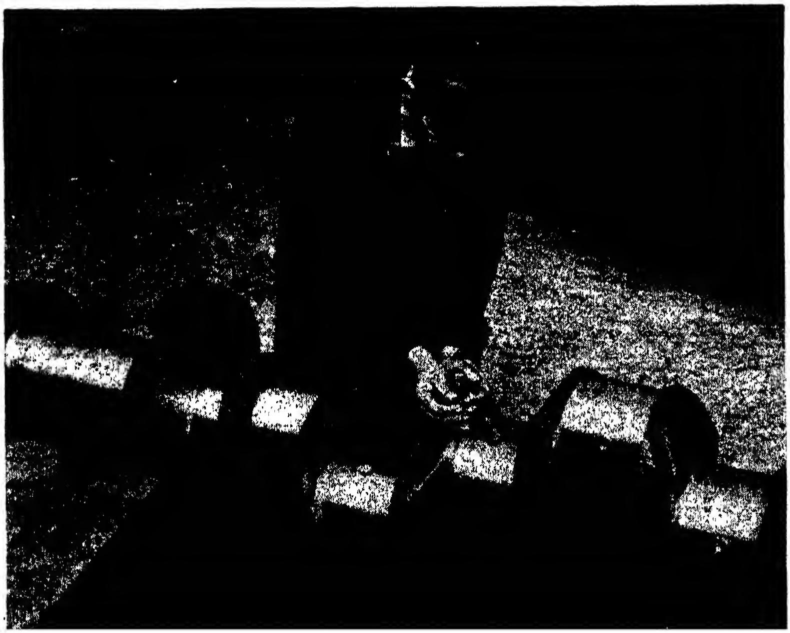


Fig. 34.—Blasting broken drills from a crankshaft.

cross heads with powder and drilled the cross heads so as to introduce the powder behind the ends of the rods. An adaptation of this idea is now being used to remove broken drills from large work such as the crankshaft shown in Fig. 34.

Crumbs or small particles of dynamite are fed down into the hole so as to reach the bottom through the flutes of the drill. Then a fuse is inserted and lighted after a heavy metal shield is at hand to place over the drill after the fuse is lighted. This method has been used by the Ohio Crankshaft Co. on thousands of shafts, which were not injured in any way by the process. They consider this preferable to the method of welding rods to

the broken drill as shown elsewhere. Figure 34 shows the fuse being lighted.

Elbow Radial Drills.—Another and very convenient type of radial drilling machine is seen in Fig. 35. This is known as an "elbow" drill because the joint in the swinging arm acts like the elbow of the arm. It enables the operator to move the drill toward or away from the center column without sliding the drill

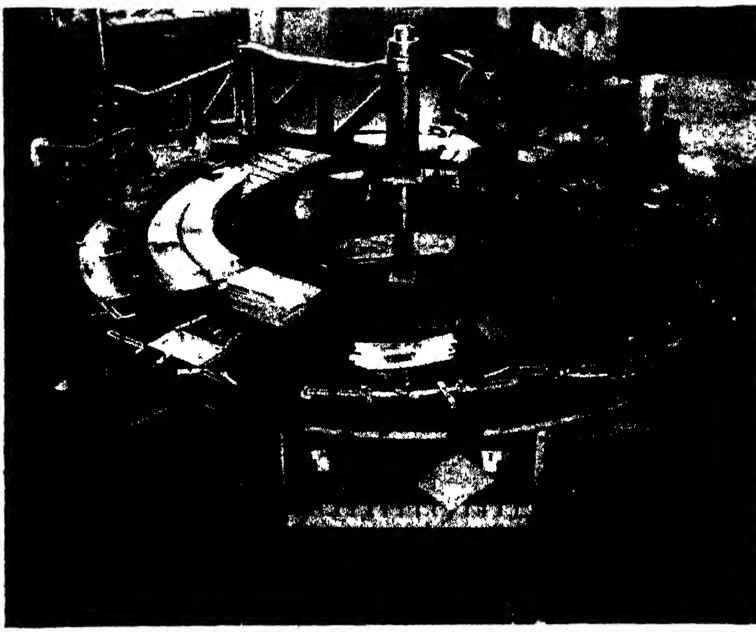


Fig. 35.—An "elbow" drill and a circular table handle a variety of work.

head along the arm, as with the standard radial drilling machine. Although this type of arm control is not so rigid as the other and cannot be used on heavy work, it is much more convenient on light work and saves time in operation. The mounting inside a circular table is unusual but allows a job to be set up at one point while a different job is being done at another, thus eliminating idle time on the machine.

Tapping Holes by Machine.—In tapping holes by machine-driven taps, the tap must feed into the work at the same rate as the pitch or lead of the thread, or the tapped hole will not be satisfactory. Either the thread will be stripped or the lead will

not be correct. Unless the tapping spindle is fed down at the proper rate by power, it must move freely enough so that, having been properly started, the lead of the thread on the tap will feed it into the hole. For this reason, positive feed is provided on some machines, as, for example, the Bakewell, shown in Fig. 36.

Here the leader *A* is mounted on the drill spindle and two followers *B*, which guide the spindle, feed the tap at the

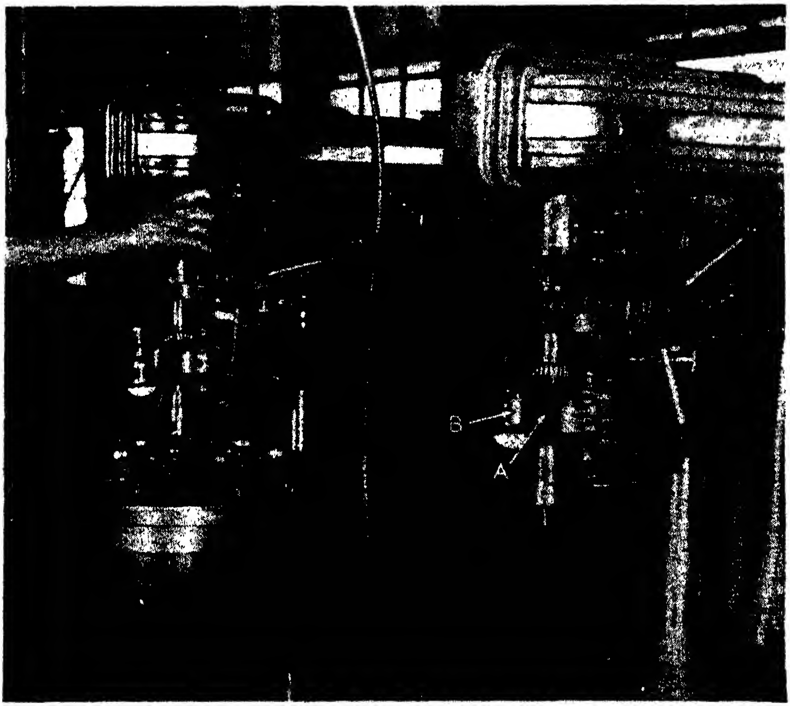


FIG. 36.—Bakewell tappers with a positive lead to the tap.

proper rate. The upper end of the leader *A* is fluted and acts as a hob to cut the thread on the followers, which are of brass. This makes it easy always to have followers of the proper lead for any thread for which leaders are provided. This type of tapper has become very popular in the aviation industry, particularly in tapping soft metals, such as the magnesium case shown.

Another very convenient tapping machine, which has the lead screw feature, is shown in Fig. 37. Here the radial arm runs in ball bearings, which enables the operator to move it in and out

as well as swing it so as to reach any location within the capacity of the machine. The spindle also moves very freely in its bearings and, as it also has a lead screw, the tap follows the lead without distortion.

In Fig. 37 holes are being tapped in an elbow type of radial drilling machine. Here the head *A* is moved up and down on the

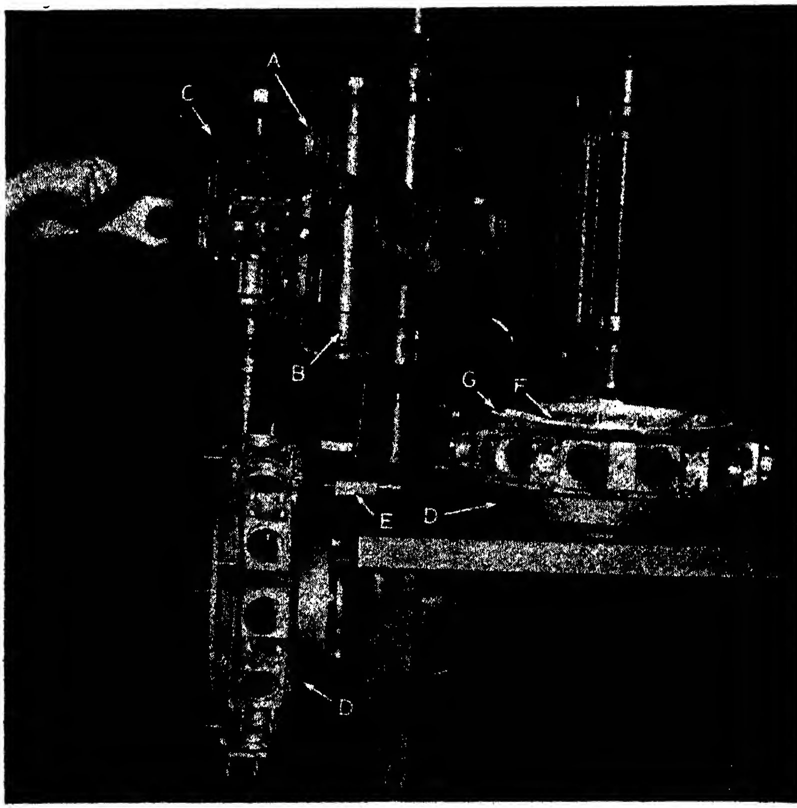


Fig. 37.—Using an elbow drill for tapping.

rod *B* by the lever *C*. It will also be noted that the drill itself is a portable tool which is clamped to the head *A*. This makes it a self-contained machine which can be moved to any part of the shop wherever power is available. The drill can be either air or electric driven in cases of this kind.

The work is mounted on the fixture *D* and can be indexed by the pin *E*. The same fixture is used as at *F* for tapping the holes

on the side of the housing, as at *G*. The flexible arm movement makes it easy to reach holes on any part of the housing.

Another type of tapping machine is shown in Fig. 38, made by the Bausch Machine Tool Co. The radial arm slides on special

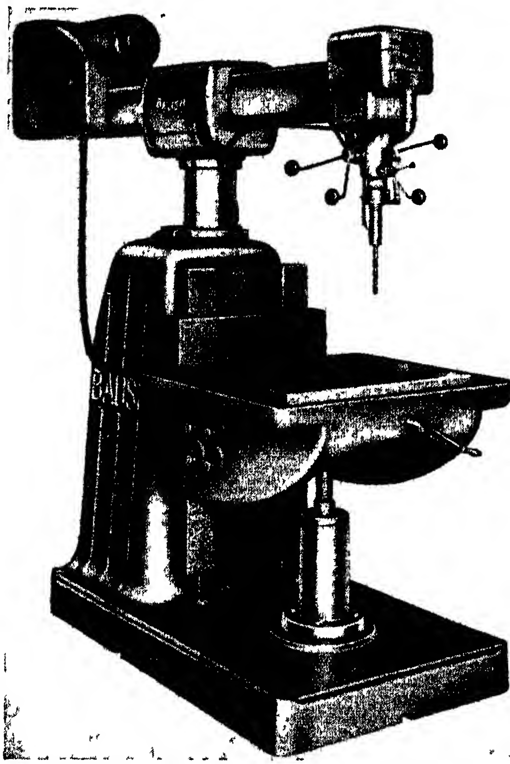


Fig. 38.—Another type of tapping machine

bearings in the head which swings in any desired direction. Although shown with a drill in the spindle, it is primarily designed for tapping and has a precision lead screw to ensure that the tap enters the work with the correct lead, as with the Bakewell machine previously shown. It has an automatic depth control and return which can be used in either drilling or tapping.

CHAPTER IV

BORING MACHINES AND BORING MILLS

Horizontal and Vertical Machines.—In order to avoid confusion, it is advisable to distinguish clearly between horizontal and vertical boring machines. Although both perform boring operations, they work in quite different ways. In the horizontal machine the work is stationary on the table, and the boring bar revolves and is fed into the work. Milling cutters are also frequently used on these machines so that they become milling machines when used in this way. In the vertical boring mill the work revolves on a table, and the tools remain stationary. They are in effect engine lathes or turret lathes stood on end. For this reason they are often called "vertical turret lathes." If we call the horizontal type a boring "machine" and the vertical type a boring "mill," which is common shop language, there should be no confusion.

HORIZONTAL BORING MACHINES

Versatility.—Horizontal boring machines of the Lucas type are among the most versatile of machine tools. Supplied with the necessary tools and operated by skilled mechanics, they can drill, bore, and mill with any degree of commercial accuracy that may be required. Where several surfaces are to be machined and numerous holes are to be drilled, bored, and faced, no other type of machine can compare with it for speed, ease of operation, and accuracy. Duplicate parts can be machined without the expense of fixtures, which more than pays for the higher wages of the operator.

Although fixtures will reduce the labor cost on large lots, builders of high-grade machines find that greater accuracy can be secured by single-point boring with a suitable machine. This is largely because of the clearance necessary between boring bars and the bushings that guide them. Where hole centers are located by a skilled man with standard distance rods and dial

indicators, some contend that the preloaded antifriction bearings of the machine itself eliminate inaccuracies due to the clearances between the boring bars and the bushings.

Where this extreme accuracy is not needed and the use of fixtures is perfectly satisfactory, the Lucas type of machine can be used as a horizontal machine to produce them. The design of this type of boring machine makes it possible to handle a great

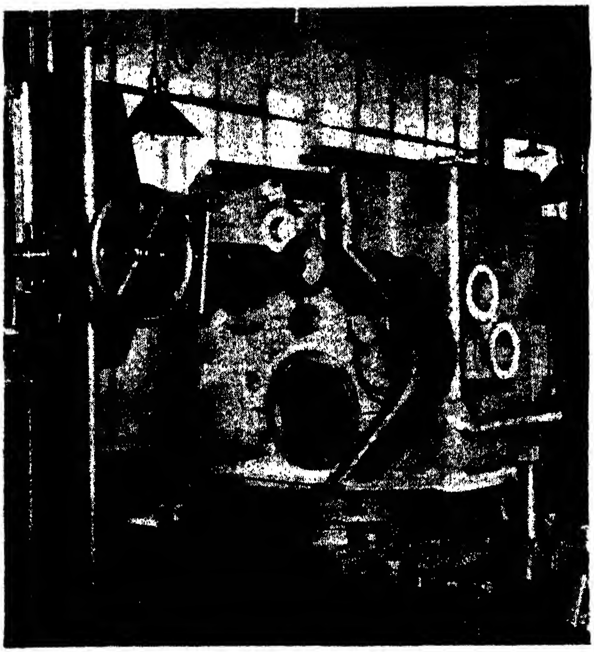


FIG. 1.—Boring one of several holes in a Lucas machine.

variety of work of all shapes and in sizes much larger than on other machines. By the use of suitable fixtures, some of which are illustrated, surfaces at different angles can be brought into position for drilling, boring, and milling, easily and accurately. Should the work warrant, a revolving table can be mounted on the machine table so as to swing the work horizontally in any desired position. This, in connection with angle plates, either fixed or adjustable, makes it possible to handle the most complicated work.

Versatility, or the ability to be adapted to the machining of a large variety of work, is one of the outstanding features of the

modern horizontal boring machine. Examples of this are seen in Figs. 1 to 3, where the operations include both boring and milling on three sides of the large casting.

With the work mounted on the substantial circular table that is built to go on the regular table, all four sides of the casting can be reached by the spindle of the machine without resetting the work. The base of the rotary table is held in position by substantial clamps, similar to those which clamp the rotary table on its base. The face of the casting, which has been pre-

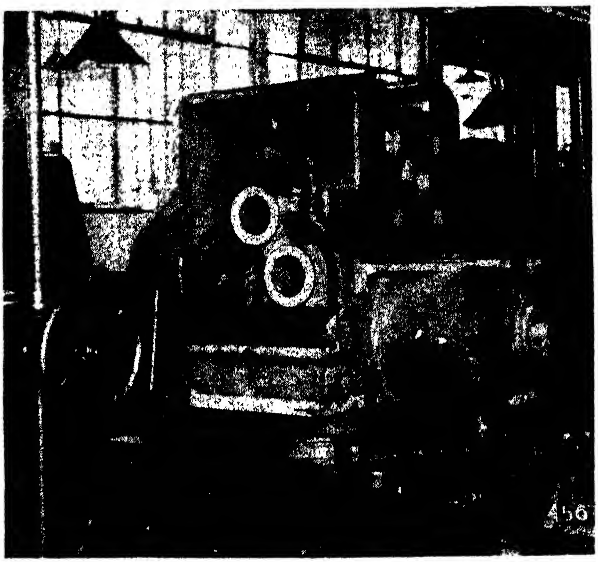


FIG. 2.—Milling with the boring spindle.

viously milled as a face from which to work, is located by the two steel blocks in the T slot of the rotary table. With the piece clamped in position, the boring bar is used to bore the various holes in their relative positions. The smaller holes are drilled with the same spindle. The vertical movement of the boring spindle head and the cross movement of the work table make it possible to locate holes correctly. Both movements can be controlled by standard distance, or length bars, and a dial indicator, the same as in the jig borer.

When the holes in this face of the casting have been bored, the table is rotated 90 deg. to bring the right-hand face in position for boring the holes and milling this face. This work is

being done in Fig. 2. The boring bar has been replaced by the milling cutter, and the face is milled by using the cross feed of the table for the horizontal parts and the vertical feed of the spindle head for the rest. Then the holes are bored at the same setting. The end now at the right has been bored previously. The overhang of this projection is supported by the jackscrew shown.

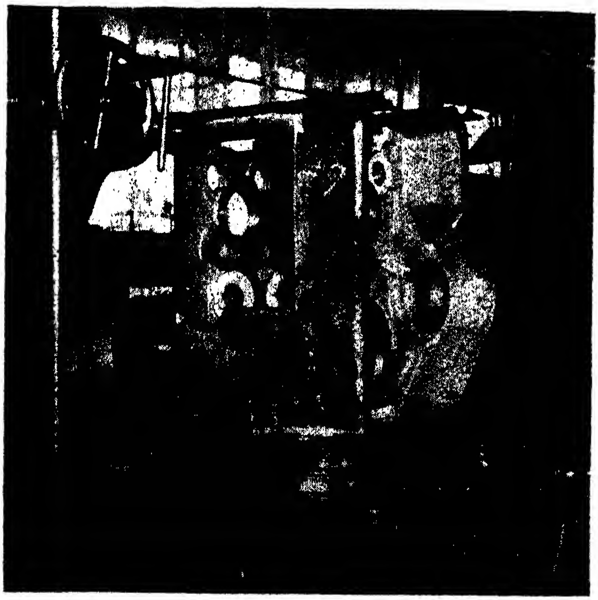


FIG. 3.—Milling the fourth side of the casting.

In Fig. 3 the face of the fourth side is being milled in the same way as the face just mentioned. This shows the locating blocks in the T slot, as mentioned before, and also the way in which the casting is held to the rotary table by the clamp inside and the side locating blocks on the face being milled. Machined in this way, the heavy casting is handled only once, and much time is saved over locating the four sides with relation to each other and securing alignment of the holes and milled surfaces.

Examples of Boring Machine Work.—Although most good mechanics and shop executives are familiar with the work done on modern boring machines, it is often easier to visualize its application in their own shop if they see work of a similar nature

being done in this way. For this reason, it seems advisable to show a number of examples of the kinds of jobs to which horizontal boring machines have been, and are being, applied in modern, well-equipped shops. Although none of these examples may be exactly the kind of work being done in a particular shop, many of them will contain one or more suggestions as to work,

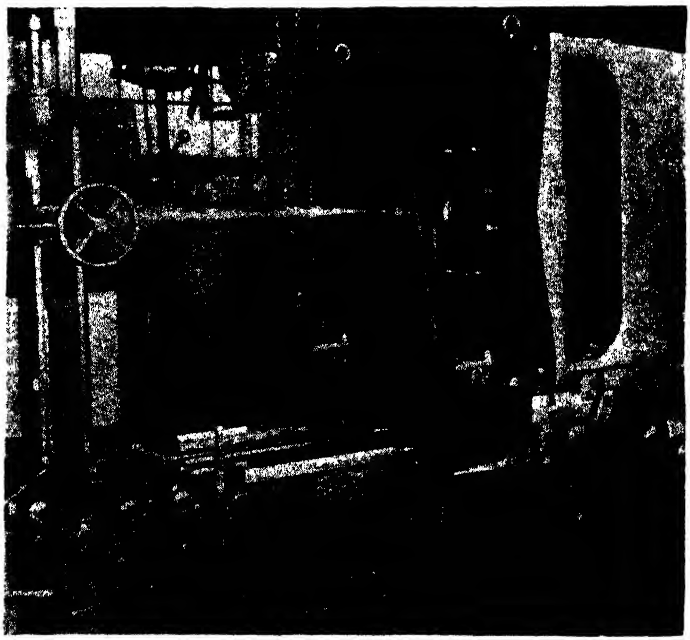


FIG. 4.—Boring several holes in a large casting.

methods of locating and clamping, or of tools and operations, that may prove of value almost anywhere. It is the ability to adapt ideas to our own use that makes us valuable to ourselves and to others.

Handling Large Work.—One of the problems in boring large work is to get it securely mounted on the machine and in the proper position. The boring itself is hardly more difficult than in smaller work.

Two large boring jobs are shown in Figs. 4 and 5. In Fig. 4 the side of the casting to be bored serves as a base for locating the piece on the table of the machine. Regular U or hairpin clamps are used, with blocks of the proper height, to fasten the

work to the table. In Fig. 5 the work is located against an angle plate fastened to the machine table and the work held against the vertical face of the angle by C clamps. There is only

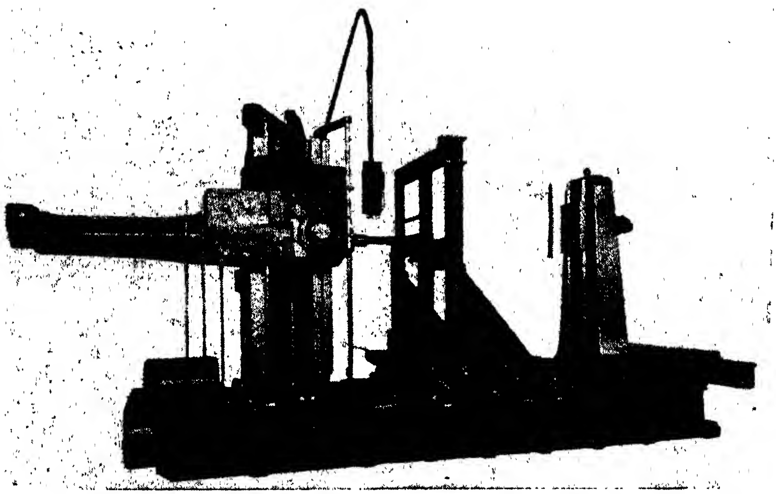


Fig. 5.—Using a large angle plate to locate work for boring.

Fig. 6.—At work on the end of a large bed casting.

one hole to be bored, the rest being drilled. But the high-speed spindle and the ease with which the various holes can be correctly located bring this job into the boring machine field.

A really big piece of work is shown in Fig. 6, this being the bed casting of another boring machine. Here the outer support for boring bars in the spindle has been removed and an auxiliary table put in its place. With this table the same height as the main work table, it is an easy matter to line up the work level at all points before the end of the casting is milled. The outer

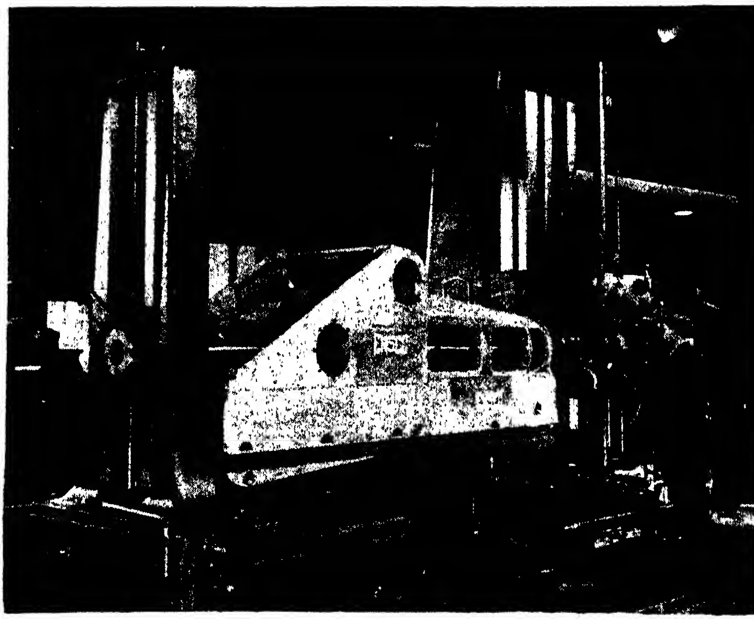


FIG. 7.—Boring a large welded pump frame or base.

support can be easily put back on its base with the crane hook in the forged eye at the top.

Boring a Large Pump Frame.—The pump frame shown in Fig. 7 is a welded unit built of steel elements. The fluid end is completely fabricated from steel forgings electrically welded. The power end is made from structural-steel shapes and plates and cast alloy steel. The bearing housings for both sides are machined in a single heavy alloy-steel casting welded integrally with the frame. This makes a very rigid construction which, with a cross type of frame design, eliminates any possibility of weaving under load.

The pump has a stroke of 16 in. and is nearly 15 ft. long over all. A large-capacity horizontal boring machine was required for the operations on the frame. The machine used is an Ohio Dreadnaught table-type horizontal boring, drilling and milling machine with a hardened and ground 5-in. spindle that can be used for slotting operations by the use of power traverse.

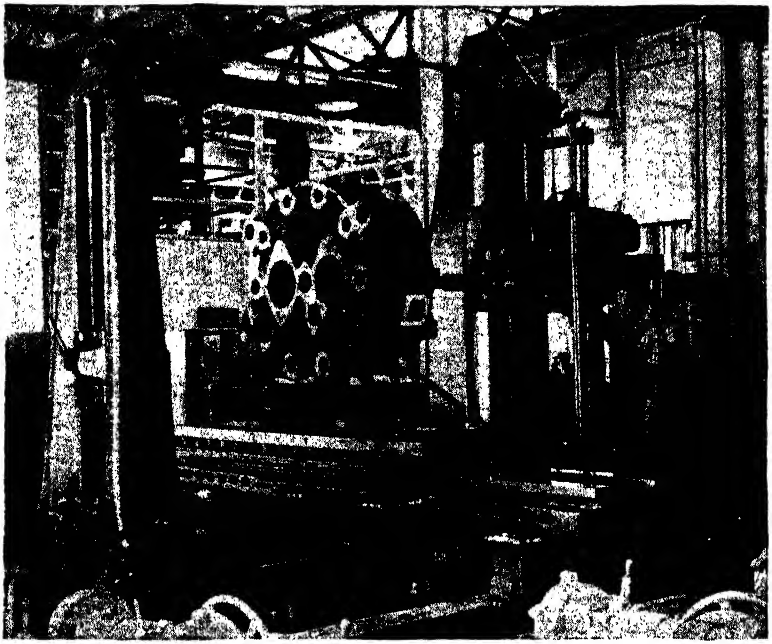


FIG. 8.—Boring a head for a diesel engine with the outer end of the bar supported.

The method of setup on the big work table is clearly shown. The size of the table is such as to permit ready setting of the job for longitudinal boring operations and for cross boring at right angles to the bearings. This is from the shops of the Emsco Derrick & Equipment Co., Los Angeles, Calif.

Boring Stud Holes and Others in Diesel Heads.—An apparently awkward job of boring on a horizontal-drilling, boring milling machine is shown in Fig. 8. This is a diesel engine head for a six-cylinder marine engine and weighs about 4,200 lb. It is for a cylinder of 29-in. bore and measures about 48 in. in diameter. The valve-cage bores are 11.023 in. in diameter, and the stud holes $3\frac{7}{16}$ in. The head is 19 in. thick.

The machine is a Giddings and Lewis horizontal with 48-in. column and 48 × 72 in. table. It has extended saddle supports and auxiliary runways. The method of mounting the work on the table is to place it on parallels of adequate height and strap it securely by means of heavy steel bars through the stud holes

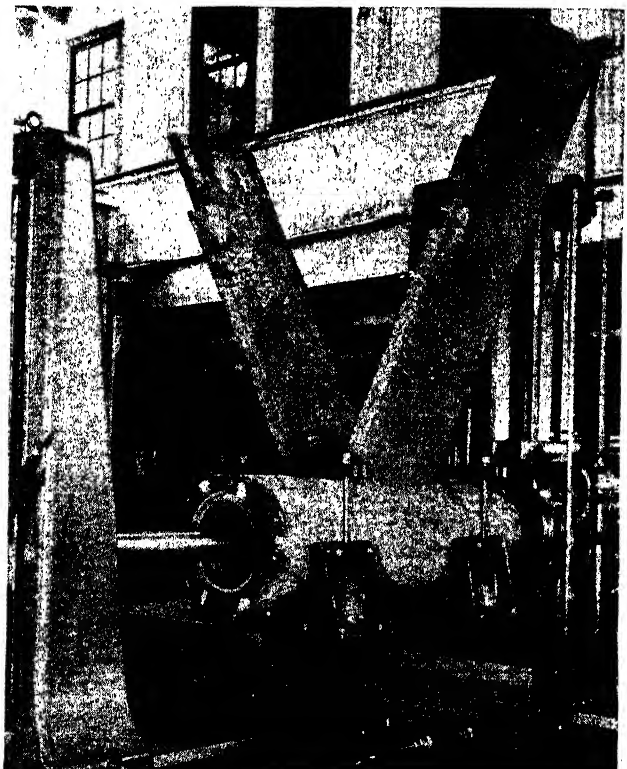


Fig. 9.—Boring a propeller strut on a Giddings and Lewis machine.

with straps over the ends of each bar. Provision against side movement is by adjustable struts against the cylindrical body of the casting.

The machine has a 4-in. main spindle and a 2-in. high-speed spindle. Boring and heavy milling are done with the main spindle, as are also such facing operations as are required on work of this kind. High-speed drilling, tapping, and milling are carried on with the small sensitive spindle which is so designed as to be as easily reversed at speeds up to the maximum of 1,500

r.p.m. as any modern drilling and tapping machine. This is in the shops of the General Engineering & Dry Dock Co., San Francisco, Calif.

Three Large Boring Machine Jobs.—Three large but entirely different jobs that come to a large Giddings and Lewis horizontal boring machine are seen in Figs. 9 to 11. The first is the boring

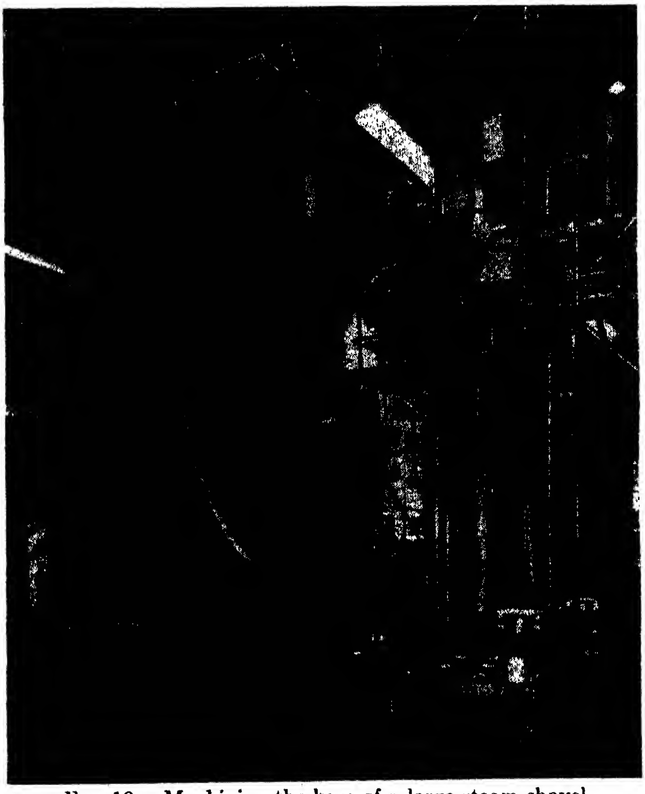


Fig. 10.—Machining the base of a large steam shovel.

of a large propeller strut which supports the tail shaft to which the propeller is fastened. This shows the method of supporting the casting on small screw jacks and clamping it between the special angle plates which have clamping screws and also pockets to receive the holding-down bolts. The clamps themselves are simply heavy bars with the ends slotted for ease in handling. The boring bar is supported at the outer end.

Figure 10 shows the base of a large power shovel mounted on the bed of a floor-type boring machine. In this case the bed of the machine moves past the boring head column, which has movement only to and from the bed. In other types, the work table is stationary, and the head moves parallel to it. The size of the

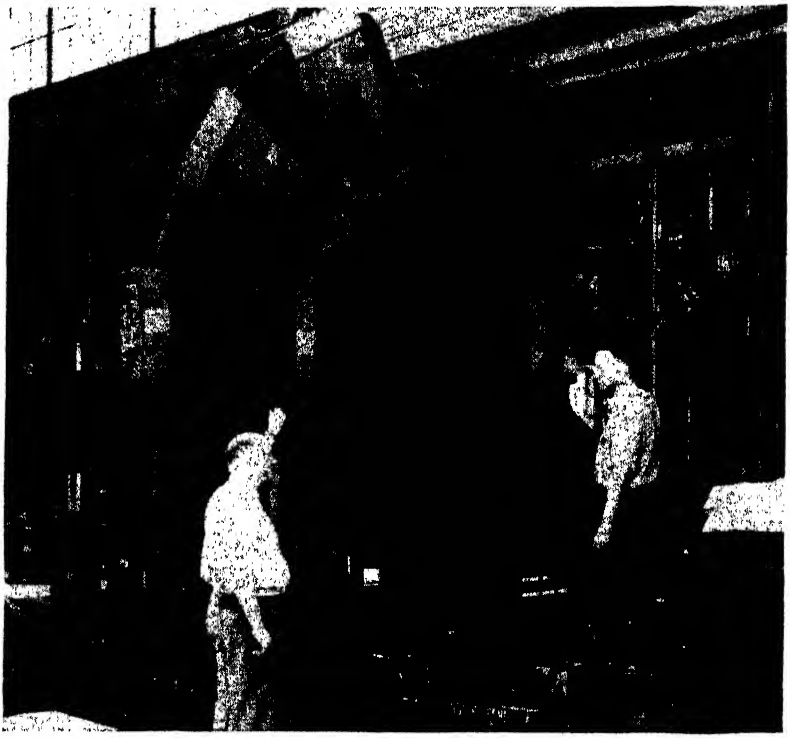


FIG. 11.—Another large job for a bed-type boring machine.

machine can be judged by the man and the platform or cage in which he works.

A large machine of the bed type is seen in Fig. 11. Here the machine is simply drilling and tapping a series of holes near the center of the base. Here again, blocking and clamping methods are of interest. This particular job could be done also under a radial drill if one of sufficient capacity were available. The choice would depend on the handling of the work and the setting up of the machine.

Machining a Large Honing Head.—In Figs. 12 and 13 are seen two setups of an unusual job on a Defiance horizontal boring machine. The spiders shown form the head for a very large honing job by the Micromatic Hone Corp. The head carries 12 honing stones, each 32 in. long for honing work, 41 in. in diameter, and 40 ft. long.

As will be seen, only half of the slots in the spiders carry honing stones; the others carry members that join the two spiders

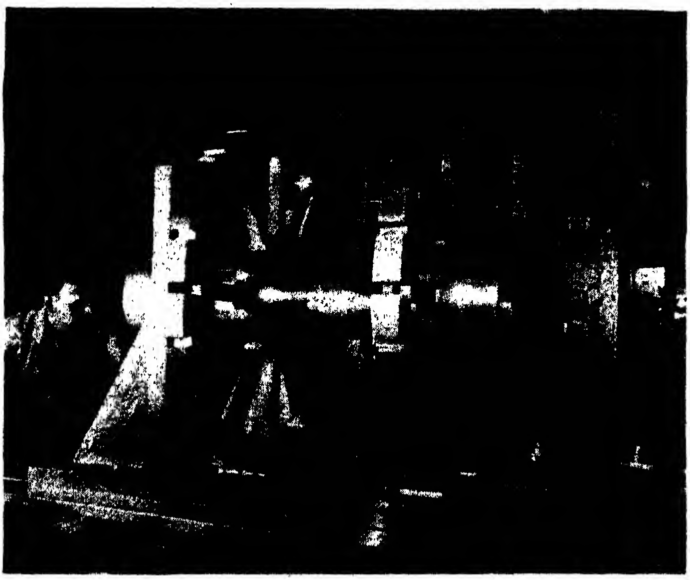


FIG. 12.—Machining the spider of a large honing head on a Defiance machine.

into one unit. Two heavy angle plates position the spiders, these being changed on the table, as can be seen, for the different operations. The indexing is done by the steel pins shown on the table under the spiders. Each pin lies in a table slot, and slots in the spiders rest on the pins. With the spiders held as shown, the slots can be milled and holes drilled in the ends of the arms. These views give an idea of the versatility of machines of this type.

Special Boring Tools.—An approach to manufacturing methods in the making of rotary pump casings is seen in Fig. 14. The lower half of the pump body is bolted to the table of the boring machine, and the complete boring is done at one operation.

The special boring bars used in this work are seen in Fig. 15, with a piece of finished work between them.

With the boring bar supported in the outer bearings, the bar is revolved by the spindle and fed down into the work to the proper distance. All the bores, including the end bearings, and the facing are done at the one operation. This ensures uni-

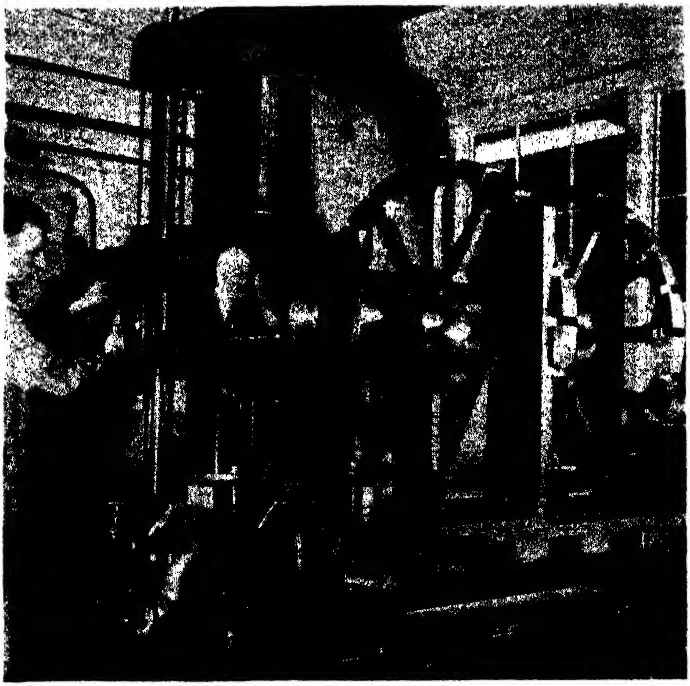


FIG. 13.—Indexing the spider for drilling.

formity and permits the work to be done very rapidly. The flange was milled and drilled in a previous operation. The mating half of the pump case was machined in the same manner.

Boring and Milling.—Two other jobs on the horizontal boring machine show more of its adaptability to a variety of operations. In Fig. 16 the drum is being drilled, bored, and counterbored at regular intervals around its circumference. The boring bar is shown in position to finish-bore a hole, and the back cutters in the bar do the counterboring as seen in the holes already completed.

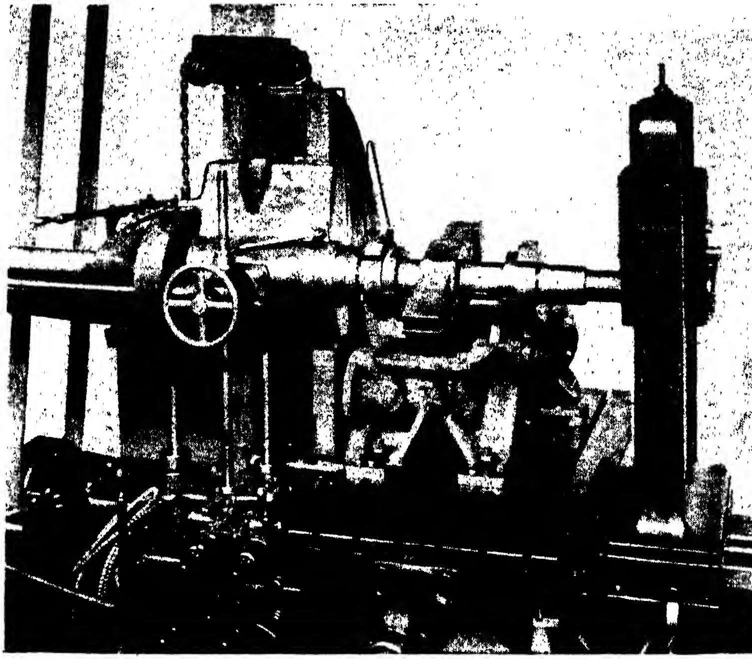


FIG. 14.—Boring a pump casing on a Lucas machine.

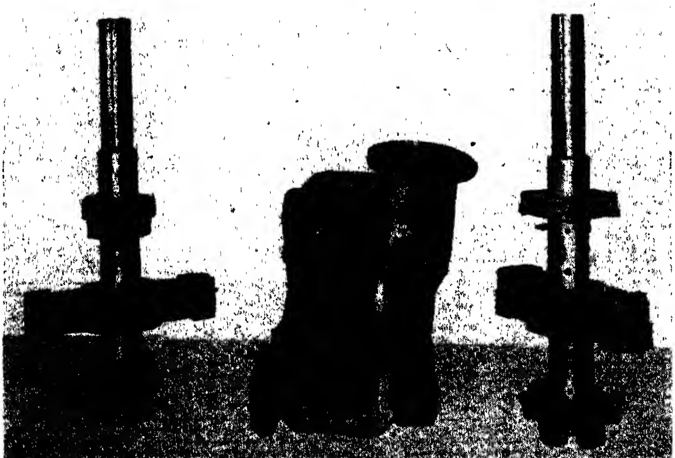


FIG. 15.—Special boring tools used on the pump case.

Where a job like this has to be very accurate, it is largely a question of accurate indexing, although the spindle must also run very true and be without looseness in its bearings. The two plug gages shown at the right of the work check the diameters of the holes after boring. By using two plugs in adjacent holes, the spacing can be checked by measuring between them. Cumulative errors can be checked by skipping a few holes and then measuring between the plugs.

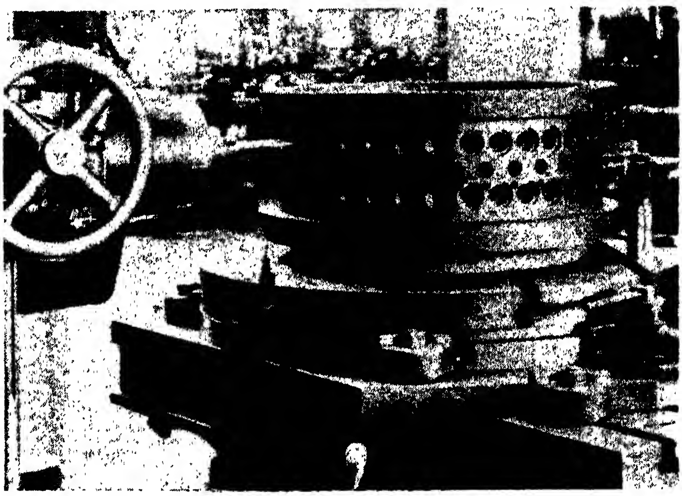


Fig. 16.—Boring accurate radial holes in a drum.

This same job could be done under a radial drill or an upright drill press by using similar indexing fixtures. It is, of course, much easier to mount and adjust the work on a horizontal table as in this case.

Boring Large Jigs Accurately.—Boring machines that are adapted to the use of standard distance pieces or measuring rods, as in the case of the Lucas machine, make it possible to locate holes in jigs with extreme accuracy. Such a job is shown in Fig. 17 where a large jig is being drilled and bored in this way.

It will be noted that the jig is supported from previously machined surfaces, on finished parallels, and located from the machined surfaces by the blocks seen in the T slots of the table. The way in which standard rods are used can be seen at the front of the table. The measuring rod or rods lie in the trough provided for them, between the fixed stop at the right and the end

of the dial gage spindle. The cover that projects the glass of the indicator when not in use is shown open.

There is similar provision for the measuring rods which control the vertical distances through which the spindle must be moved. With the holes laid out in both horizontal and vertical distances, as is now common practice, it is easy to locate any

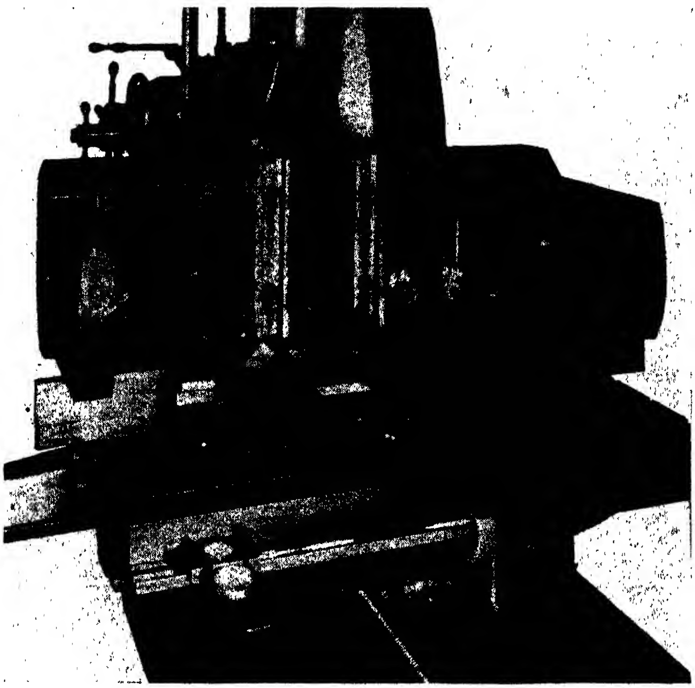


FIG. 17.—Locating and boring holes in a large jig.

hole in the desired position within a very close tolerance. This is considered much more accurate than depending on the accuracy of lead or feed screws with micrometer dials.

Distance rods, the same as gage blocks, are too delicate and costly to be left lying around on the machine. When not in use, they are kept in suitable cases similar to the one shown on the machine table. Combining different rods gives the required measurements, as with gage blocks.

Emergency Boring Fixtures.—An excellent example of an emergency boring fixture is shown in Fig. 18. This is from the Continental Motor Co. plant at Muskegon, Mich., and was

built for work on the radial airplane type of engine made for tanks during the war. . This fixture was used on an old Rockford horizontal boring machine and did excellent work. The old Rockford machines were not intended to do precision work, but to supply power for boring bars. They were located and guided by the fixtures in which the work was held. Accuracy depended on the fixture, which is the logical method in all cases of this kind.

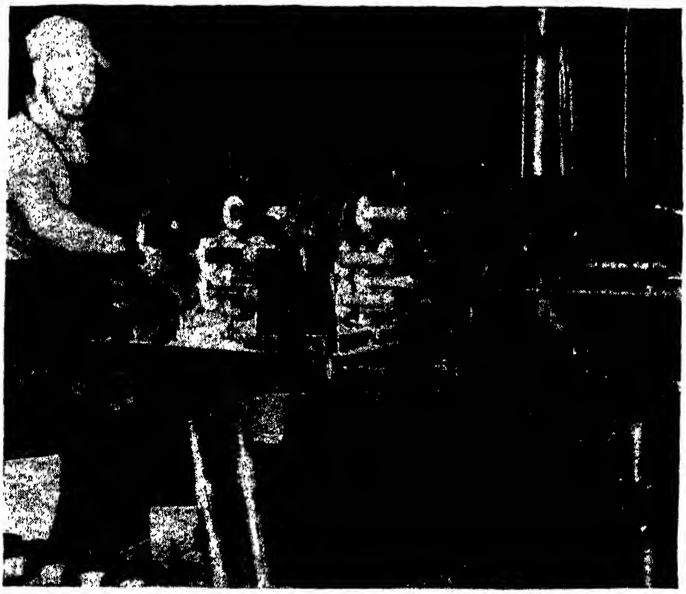


Fig. 18.—Utilizing an old boring machine on a war job by using an accurate fixture.

These holes were originally bored, one hole at a time, but the fixture shown carries seven boring bars from a special geared head which is in turn driven by the single spindle of the old machine. The bars are connected to the seven spindles in the geared head by the bayonet-type clutches or couplings shown.

Homemade Boring Machine for Cylinder Liners.—A special job put through the shops of the General Engineering & Dry Dock Co. in San Francisco consisted of the boring to size of a large number of diesel engine liners. The work was handled in a homemade horizontal boring machine built up especially for the work on these liners. This shows one of the advantages of portable boring bars.

Illustrations of the machine in actual operation are reproduced. Figure 19 gives a good idea of the complete machine. Figures 20 and 21 show details of construction and certain features in connection with the boring bar and cutter head.

This machine is built up on an old planer table which is itself mounted on heavy 16-in. I beams for rigid support. To these I beams the table is secured by a series of large setscrews set into counterbored seats from the top of the table, the holes then

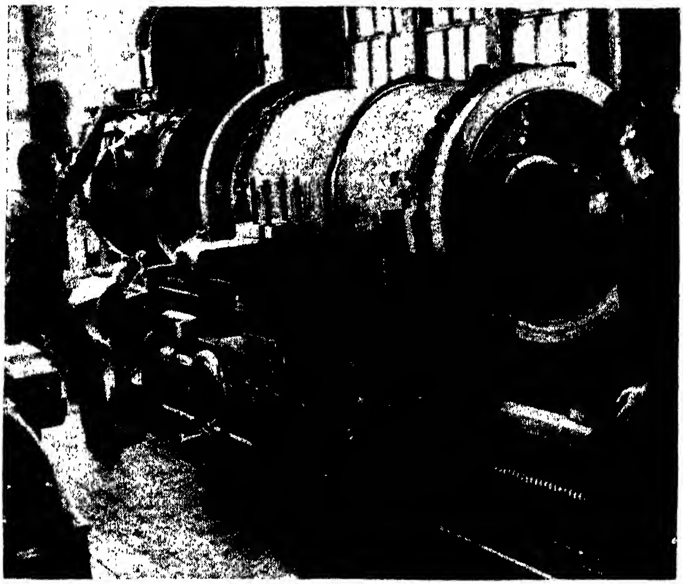


Fig. 19.—A homemade boring machine used on marine engines.

being filled flush over the heads to give a smooth table surface. The table is 16 ft. long by 48 in. wide and acts as a complete bed for the boring mill.

The liners being bored form a lot for single-acting two-cycle diesel engines of 8-cylinder type. The bore of the liners is 21 in., the length 54 in. There is an average of ⅜ in. of stock to be bored out of these castings all the way around. Three cuts are normally required.

The boring is done with cutter heads carrying Carboloy-tipped tools in a spider head mounted on a 10¾-in. boring bar which is cast hollow and is ground to exact size from end to end to permit

the cutter head to slide smoothly and without chatter as it is fed along the bar.

The drive is by a 10-hp. variable-speed motor with range from 400 to 1,600 r.p.m. By suitable gearing any necessary rate of speed is available for the boring bar. This speed range runs from as low as $1\frac{1}{2}$ to 22 r.p.m. In a bore of the size shown the speed range available would represent a possible variation in

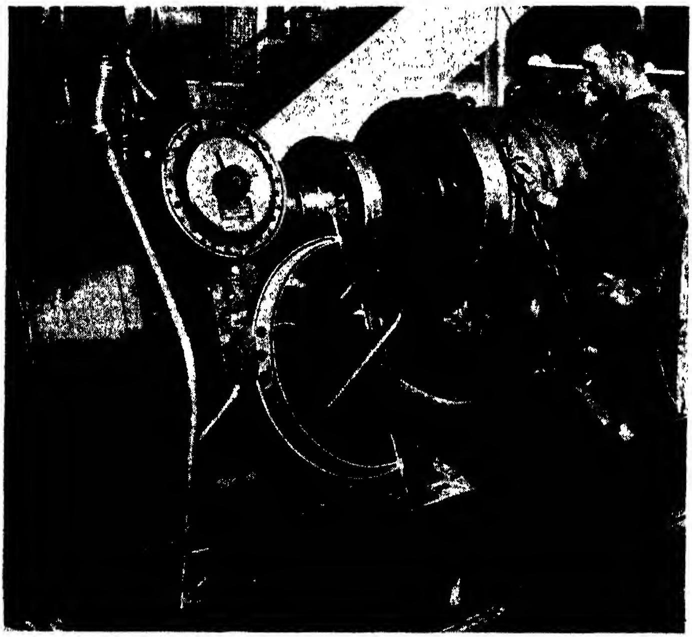


FIG. 20.—Head end of boring machine. Note collapsing cover for boring bar.

surface speed of the boring tools equivalent to 8 ft. per minute as the lower point to 120 ft. per minute as the maximum rate obtainable. Consequently, this special machine unit lends itself to the handling of a considerable variety of work of generally similar character but varying in respect to diameters, type of metal, and other characteristics.

Star feed is used with contacts at each revolution of the bar. The operating studs are mounted in a swinging bar or gate which can be swung out of the way when the feed screw is to be operated by hand or by rapid motion with air motor or otherwise. The screw is 5 threads per inch.

The bore in the liner is held to a tolerance of 0.002 in., which is very close work for a job of this character.

The boring bar is kept clean and free from chips and dirt during the feeding of the cutter head along its surface by a flexible guard sleeve which is dragged out automatically to cover the bar at all positions of the boring head.

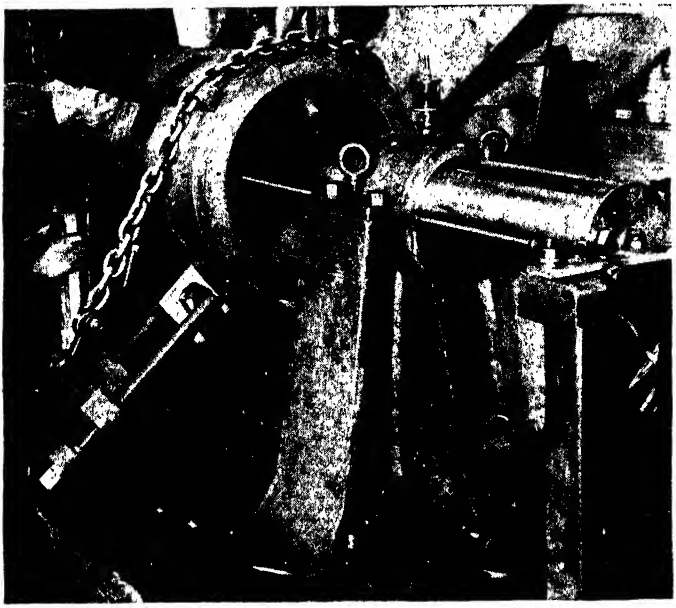


FIG. 21.—Back end of the machine (Fig. 20) showing support for the boring bar, the screw that feeds the tool, and the star wheel at the end of the screw.

The boring heads are shown in both Figs. 19 and 20. Figure 20 shows also the protecting sleeve withdrawn or collapsed to the closest degree upon the withdrawal of the head to the starting point of the bore. The three Carboloy boring tools are mounted in separate holders 120 deg. apart and are adjustable and secured by hollow-head screws as indicated. Although these carbide tools have to cut on interrupted surfaces due to the cored ports around the center of the liners, they stand up without fracture at any rate of speed at which the boring operation is carried on.

The method of mounting the liners in their rests or supports on the bed plate, and the screws for adjustment for position and chains for clamping the liners securely, are all plainly shown. Similar methods can be used in many cases.

Oil Grooving Driver Box Brasses.—A driving box for a 9-in. axle is shown set up under a drill press in Fig. 22. The drill is equipped with a special rig for cutting the grease grooves, both straight and helical, by means of an end mill which is adjusted to the proper depth by the hand knob shown on the side of the milling head at the lower end of the spindle.

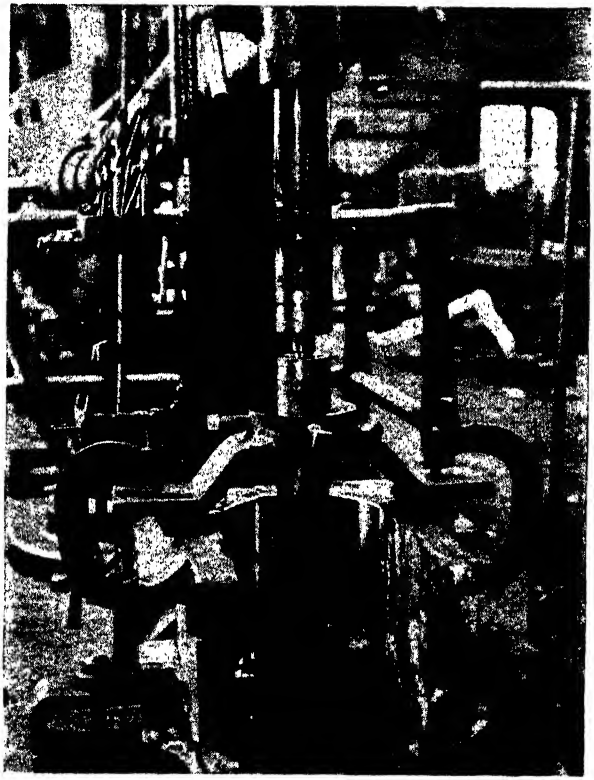


FIG. 22.—An improvised method of cutting grease grooves in a locomotive driving box.

The drive is from the spindle of the drill press and is equally effective for straight or helical cuts. With this tool the practice is to use a short drill in the milling head at the outset for placing a starting hole at top and bottom positions of the parallel cuts. This drill is fed into the surface to predetermined depth, according to the size of the box, by means of a screw feed behind the tool holder. Then the drill is replaced by a stub end mill which, like the drill, has a taper shank for securing it in the spindle. The

latter is driven by bevel gearing from the vertical shaft which is provided at its upper end with a taper shank fitting the drill press. The full depth of cut, ½ in., is taken at a single pass along the work.

The spindle of the device for carrying either drill or cutter is short and runs in ball bearings. The vertical shaft driving this shaft through the bevel gears referred to is mounted in a quill whose outer wall is provided with both straight and helical guide grooves to correspond with the grooves to be produced in the bearing surface. Two opposite setscrews with pilot ends placed in the yoke surrounding the quill act to guide the quill in its downward feeding movement, whether straight or helical cuts are being made. The two parallel longitudinal cuts lengthwise of the brass are first milled, than the screws are withdrawn and the quill turned around to admit the guide screws to the helical guide grooves in the quill. The two spiral or helical cuts are then made, and the milling head is raised to position for milling the grooves parallel to the end of the box for connecting the two longitudinal grooves.

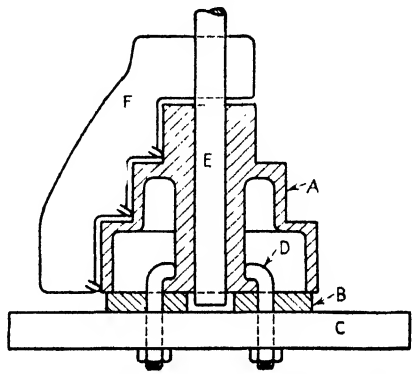


FIG. 23.—Turning a cone pulley with a sweep tool.

Turning and Boring.—Both turning and boring can be done by any one of three methods: by revolving the work or revolving the tool, or both. The method to be selected depends largely on the equipment and the tools available, as well as on the training of the men who are to do the work. There is usually one method that is the best to use in any particular case.

Shops building a given line of machine tools are likely to use their type of machine even when it is not the most economical for the purpose. This is frequently done because the shop has these machines on hand and does not have the type they might prefer to use if they were available.

When sufficient engine lathe capacity was not available, one shop turned cone pulleys with a sweep tool as shown in Fig. 23.

Casting A was first bored and faced on the lower end and at the surfaces between the steps of the cone. It was then fastened to the table of a drill press, the large turned end resting on plate B, which in turn rested on the drill press table C. The cone was held down by the hook bolts D bearing against the enlarged end of the hub of the pulley. The sweep tool was mounted on bar E which fitted the bore of the pulley and the three turning tools mounted on the arm or wing F. As shown, the cut is nearly completed, the three tools being fastened in the conventional way by straps bolted to arm F. Although this is not a very substantial rigging, it was used in making a large number of cone pulleys for a machine tool builder who has now grown to sizable proportions.

A similar method could be used in an engine or other lathe. In that case, the pulley would be mounted on the faceplate, and the wing carrying the cutting tools would probably be supported on the cross slide of the lathe carriage.

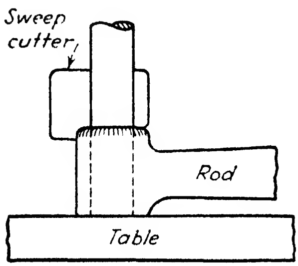


FIG. 24.—Finishing the end of an airplane-engine connecting rod with a sweep tool.

This is very similar to trepanning, which is sometimes done in a drill press but more often in a vertical milling machine, as will be seen in Chap. VI. In all work of this kind the support of the cutting tool is most important and sometimes very difficult. The springing of the tools and of the work must be very carefully considered in adopting this method of machining. Similar but usually much simpler operations are often done on the production line in larger shops.

An example of this is seen in Fig. 24 where the boss on the end of a link rod of a radial airplane engine is being turned concentric with the bore for the knuckle pin. Here too the sweep cutter is guided by the pilot which goes into the hole in the end of the rod.

This same job was also being done in the same shop on a vertical-spindle milling machine using a rotary table to rotate the rod under the milling cutter. This is a case where the simpler method, the drill press, is the most economical in every way. It takes a less expensive machine; the sweep tool should cost no more than the milling cutter with the proper radius on the corner; and the drill press requires only a very simple fixture to hold the work.

Sweep-type tools can also be used where the work revolves and the tool remains stationary. Many turret lathes use tools of this kind in much the same way as they use hollow mills on small-diameter work. Tools of this kind are frequently arranged on slides to permit radial feeding into the work.

Where the work revolves the tool is fed along the work for turning or into the work for boring. Where the tool revolves it is also fed into or over the work in most cases. With the horizontal boring machine, the revolving spindle carrying the tool is fed into the work; the same is true of the vertical boring mill except that the tool does not revolve. With the horizontal machine the work is stationary but with the vertical boring mill it revolves.

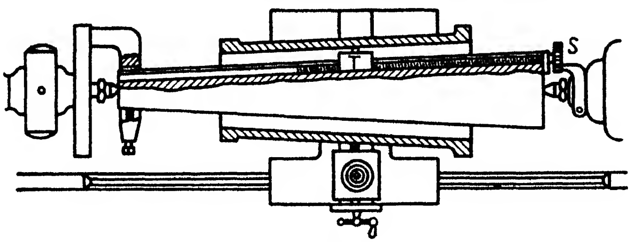


FIG. 25.

Portable Boring Bars.—Portable boring bars can also be used to advantage in many cases. They can be used in a lathe or independent of any machine, driven by their own motor or by a belt or gearing. Examples of these are shown in Figs. 26 to 30.

In the illustration, Fig. 25, the work is held stationary on the lathe carriage while the tapered boring bar is held between the lathe centers and is driven by the dog at the left. The tool *T* is fed along the bar by means of a screw, the tool holder acting as a nut which the screw moves along the bar. A spoked or pronged wheel on the end of the screw is turned one tooth by a stationary pin shown at *S*. This is known as the "star wheel" and this method of feeding is called a "star feed."

Where one pin is used, the feed is one tooth or spoke of the star wheel per revolution. This can be increased by using two or more pins so that the screw will be turned two or more spokes at each revolution of the bar.

With this type of boring bar, either a straight hole or a taper hole can be bored. With the work driven by the faceplate, a straight bar can be set off at an angle by the tail center of the

lathe and a taper hole bored with a straight bar. Or the bar can be made of the taper desired and the tool fed along the tapered side of the bar with the bar itself held parallel between the centers.

Portable boring bars were originally designed for such work as the reboring of cylinders of locomotives without taking them off the locomotive, or for reboring large marine engine cylinders in place.

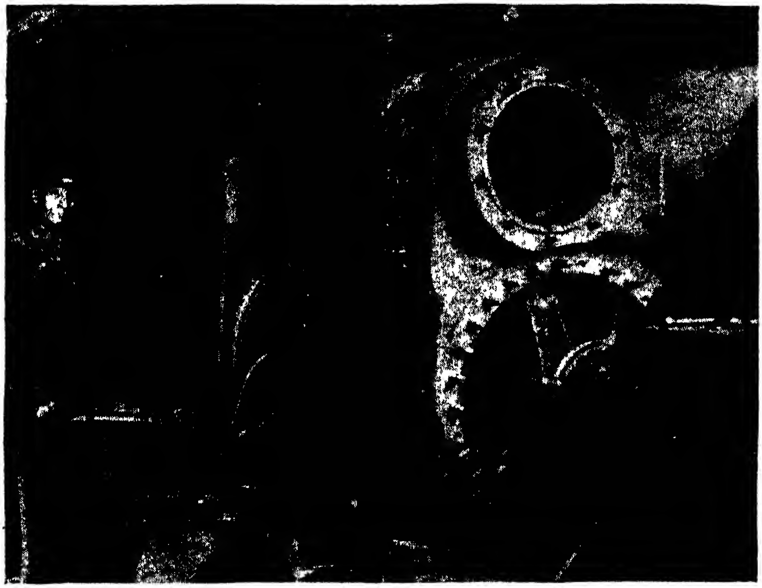


FIG. 26.—Boring locomotive cylinders in place with Underwood portable bar.

Several examples of the use of portable boring bars are given in these pages. These show the type of portable bars made by the H. B. Underwood Co. of Philadelphia who have specialized in this sort of work for many years. Figure 26 shows how such a bar is set up for reboring the cylinder of a locomotive in the roundhouse, taking it out of service as short a time as possible. This shows how the bar is supported by cross pieces at the ends of the cylinder, bolted to the studs that hold the cylinder head in place. Power in this case is supplied by the air drill shown lying on the bench in front of the operator.

Another roundhouse setup is seen in Fig. 27 where boring bars are in place in both the cylinder and the valve chamber. Here

the large bar in the cylinder is driven by an air drill as before, but the smaller bar shows a pulley for a belt from any convenient source of power. The driving gear train is in the housing beside the pulley. In both of these boring bars, the old star feed has been replaced by a positive-geared feed which can be seen at the end of each boring bar. This gives a uniform feed to the tool

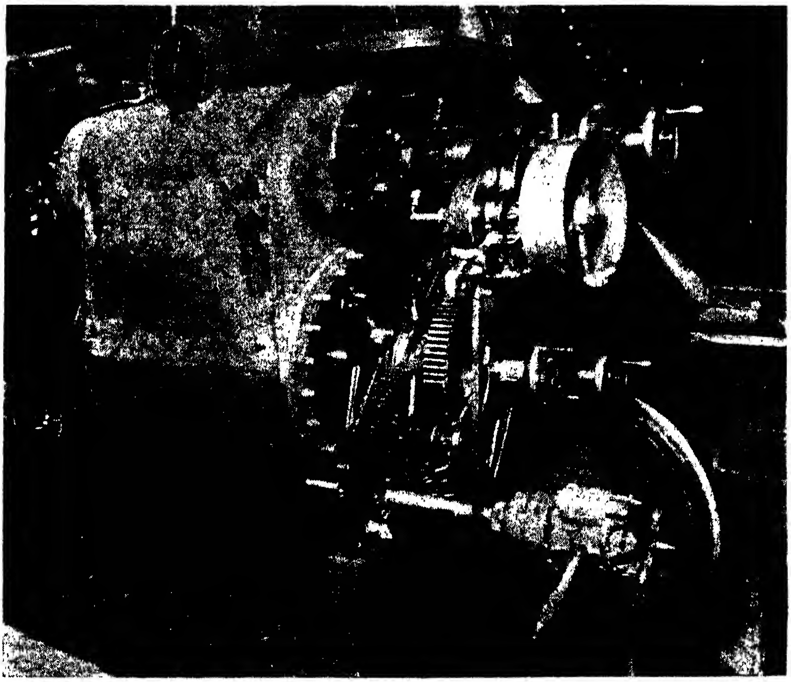


FIG. 27.—Another portable boring rig at work on both cylinder and valve chamber.

instead of the intermittent feed given by the star feed. This is one of the features developed by the Underwood Co. It is easier on the cutting tools and does a more workmanlike job.

An unusually large job is seen in Fig. 28 where three bars are set up on a large casting. Here the power is supplied by a small steam engine belted to the type of pulley drive shown in Fig. 27. A similar steam engine is seen at the other end of the casting driving one of the other bars. In modern practice an electric motor or an internal-combustion engine would be used instead of the steam engine.

One of the outgrowths of the portable boring bars is seen in Fig. 29, where a bar of this type forms part of a horizontal boring machine in a large shop in which cylinder boring is part of the regular work. This is a large locomotive-building plant, the cylinders being part of the frame and all being cast in one piece. Here the boring bar is supported in bearings on substantial uprights, these being mounted on a large bedplate which supports

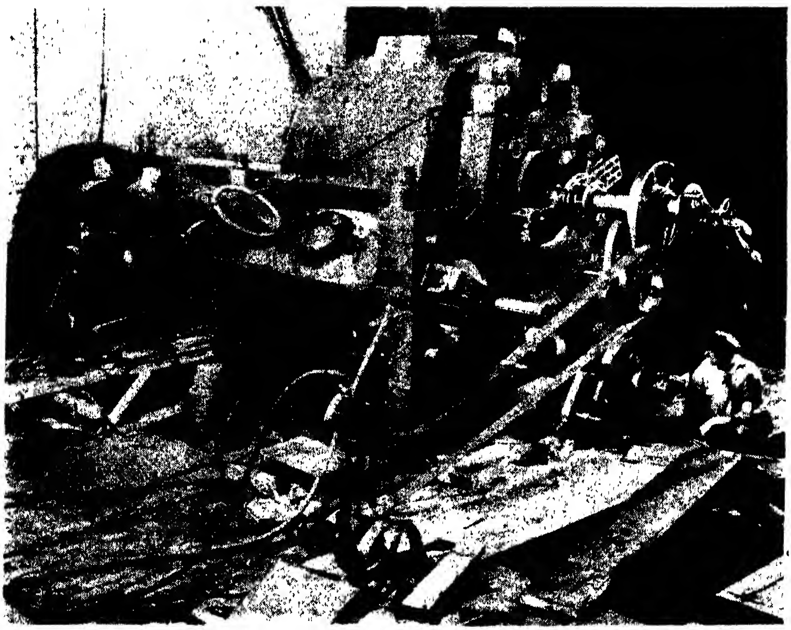


FIG. 28.—Using three boring bars on a large job. Steam engines used for power.

the locomotive frame itself. This bar is driven by a worm which gets its power from the electric motor seen at the right. This might be called a "semiportable" boring machine.

In some cases, in shops not supplied with boring mills large enough to handle the work, cylinders for the engines of Liberty ships have been bored with portable bars. The work is handled in the same way as for smaller cylinders but, on account of the size, it becomes a major operation and takes the place of large machine tools.

Another method of boring that should not be overlooked is the use of some of the well-known makes of cylinder boring units

that have been developed especially for reconditioning automobile cylinder blocks. These boring tools have proved very useful in the boring of cylinders and can be used in many places instead of expensive maching tools. They are of course strictly a repair or maintenance tool and are not designed for quantity-production work.

Boring Locomotive Cylinder Bushings.—The boring job in the lathe, Fig. 30, is the machining of a bushing for a 22 x 28 in

FIG. 29.—Using portable boring bars as part of a cylinder-boring machine in a large locomotive shop

cylinder for a switch engine. This job is set up in special rests forming a fixture with a number of setscrews for adjusting the casting to central position before starting the cut. These cathead chuck fixtures are set up securely for holding a heavy casting during the boring operation. With work indicated true with the boring bar, the boring is done with three tools in the spider boring head on the bar. The tools are arranged for offset boring with the roughing tools staggered ahead of the finishing tool.

The single tool shown is for counterboring the clearance diameter at the ends of the cylinder. This enlarged cut at the ends is finished after completing the bore through the cylinder and is followed by a chamfering cut with a single tool held in the

same manner as the counterboring tool. After boring, the bushing is turned to outside diameter by being mounted on a spider mandrel.

Boring Operations.—Although boring is usually considered as the enlarging of holes that already exist either from previous drilling or from holes punched in forgings or cored in castings, the term is sometimes applied to producing holes in solid metal. The term is usually applied to holes of fairly large size, larger diameters than are ordinarily produced by drilling. Drilling

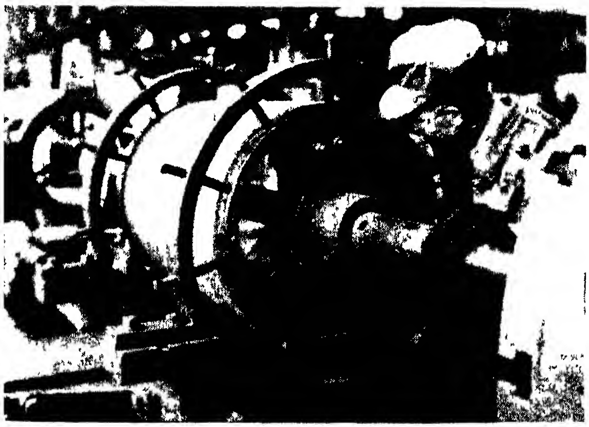


FIG. 30.—Boring a locomotive-cylinder bushing in a lathe.

is usually considered as producing holes not larger than 3 in., although there is no hard and fast rule regarding it. In such cases the operation is usually referred to as "boring from the solid" which has been done quite extensively in the case of cylinders and pistons for the hydraulic or "oleo" landing-gear struts for airplanes.

Such a case is shown in Fig. 31 where the hole is 3⅛ in. in diameter and shows the work done by the Canadian Car & Foundry Co. on oleo landing gear for Hurricane fighters for the British.

The hole in the oleo cylinder is 3⅛ in. in diameter and 26 in. deep. As the forgings are of chrome-nickel steel and Brinell over 300, they are extremely hard.

The boring bars were made of 1040 steel, heat-treated 3½ hr. at about 1500 deg. F., quenched in oil and drawn to 700 deg. F. This gave a Rockwell C hardness of 51.

Details of the construction of the boring bar are shown in Fig. 31. This shows how the spade-shaped cutter is held and the chip space milled beside the oil tubes, which are sunk in the body of the bar. The spade cutter is of high-speed steel with chip-breaking notches that are not shown. A cutting angle of 31 deg., a cutting clearance of 10 deg., and a side clearance of 6 deg. proved very successful in practice.

Coolant at 500 lb. pressure removed the chips and the heat of cutting. This type of bar can be used in either a heavy-duty

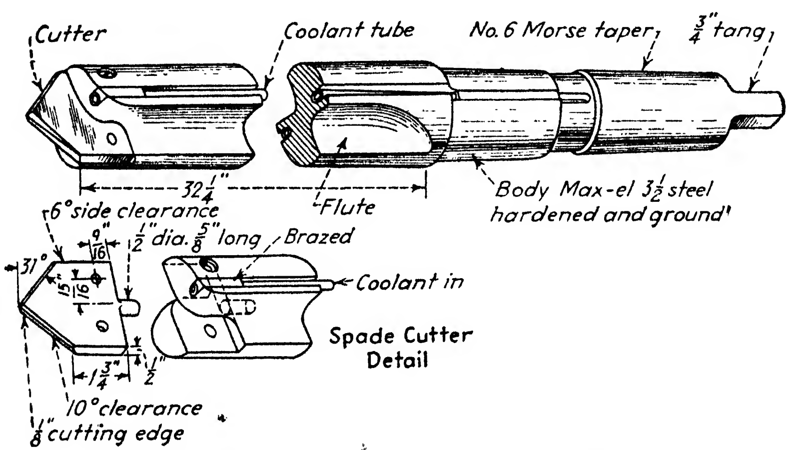


FIG. 31.—Canadian boring bar for airplane landing-gear struts.

drilling machine or a turret lathe. In the Canadian Car and Foundry Co. it was most successful in a Barnes two-spindle, inverted drilling machine. It proved several times faster than boring bars used previously.

Deep-hole Boring.—Deep-hole boring for such mechanisms as cannon, long hydraulic cylinders, and similar work has always been considered work for a special boring lathe. Most of these lathes have a bed more than double the length of the piece to be bored, to accommodate the work, and a boring bar long enough to reach through it. When the boring lathe has a spindle with a hole large enough for the work to go inside of it, the length can be reduced somewhat. But when the boring bar must extend from the boring head for the whole length of the bore, a very long bed is necessary. The length must also provide for a support for the bar as near to the end of the work as possible.

In 1942 some antiaircraft guns were bored in a lathe about the length of the gun forging in a Texas shop accustomed to making oil-well tools in a very efficient manner. In this case the gun was almost as long as the lathe bed. But the lathe spindle was hollow and allowed the end of the gun to be held inside of it.

The tailstock was removed from the lathe, and at the end of the lathe a framework was built to hold a hydraulic cylinder which supplied the feed to the boring bar. This framework was bolted to the floor in line with the lathe bed and spindle. The piston or ram of the hydraulic cylinder formed the boring bar. A cutting head was formed on the end next to the work. Using the hydraulic cylinder as the feed, the cutter head was forced into the gun forging. The cutter was supplied with lubricant under heavy pressure to wash out the chips and to keep the cutter cool. The boring was done very successfully and at a rate equal to the average lathe built for the purpose.

In a modification of this method the tailstock of the lathe is removed and replaced by a head that supports and guides the boring bar. The bar feeds through the head that supports it. Various ways of feeding the bar are possible. A simple method is to use a rack recessed into the underside of the boring bar. Guiding keys or feathers should also be used to prevent the bar from turning in its support under stresses imposed by the boring cutter in the work.

Feed can be obtained in several ways. The feed motion can be imparted to the rack by a worm-driven spur or helical gear or by a worm working directly in the rack in the same way that a Sellers planer bed is driven. This makes a very smooth form of drive for feeding the bar into the work. In any case it is necessary to provide sufficient pressure to force the boring cutters into the work. It is also necessary to provide a trough for the chips and lubricant as they come out of the bore.

With this method, the lathe bed need be only long enough to support the work in one or more steady rests and provide room for the head that carries the boring bar. If it has a hollow spindle that will take the work, the length of the bed can be considerably reduced.

The overhang of the outer end of the boring bar can be supported in a number of ways. The simplest method is that used in supporting the ends of bar stock used in automatic screw

machines. Ample power should be provided for the feeding mechanism, as it takes more power than many realize to force a cutter into a block or bar of solid steel.

Trepanning Locomotive Side Rods.—In cutting out locomotive side-rod ends preparatory to finishing out to size on the internal grinding machine, the trepanning tool is especially useful as a means of saving time in cutting out the stock and enabling the job to be got out of the machine at the earliest moment.

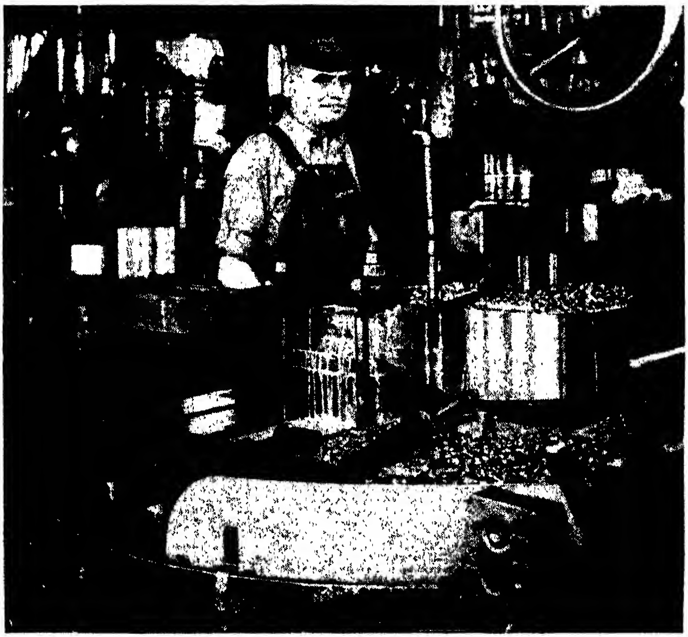


Fig. 32.—Trepanning the bore of a locomotive connecting rod.

The practice at the Southern Pacific shops in Sacramento is to use a trepanning tool, which is operated in the Ingersoll vertical milling machine, as illustrated in Fig. 32. The trepanning tool is also illustrated by reproduction from a shop print in Fig. 33.

The method of mounting on the table of the heavy milling machine is quite clearly seen in the photograph, and the heavy character of the chips removed under the trepanning cutters is equally clear. A flood of coolant is, or course, an essential feature in performing this operation, which means the cutting of a deep and relatively narrow circular channel through the rod end to provide the large bored opening for the bushing or rod brass.

Referring to the drawing of the trepanning tool, the body of this device is made up of a tool holder proper pressed onto a $2\frac{1}{2}$-in. arbor with Morse No. 5 taper shank to fit the milling machine

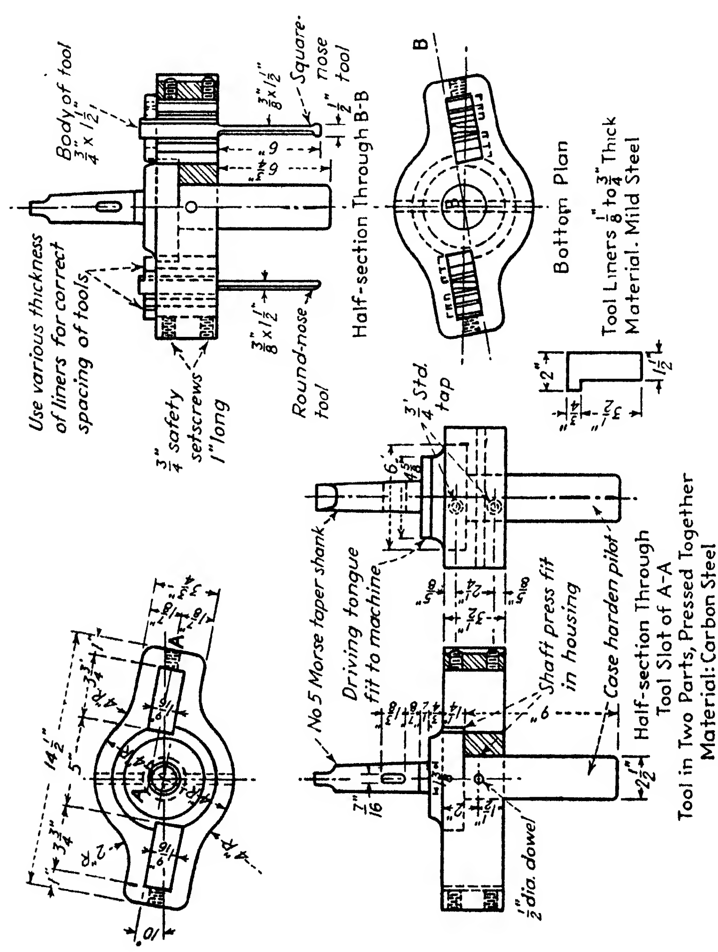


FIG. 33.—Detail of the tool used in trepanning the connecting rod.

spindle. A ½-in. dowel is also fitted as shown. The 2½-in. diameter forms the pilot for the tool when in operation. This is casehardened as indicated on the drawing.

The body of the tool is a heavy steel block finished 3½ in. thick and provided with two tangential slots 1$\frac{9}{16}$ in. wide by 3¼ in. long; these slots being cut at an angle of 10 deg. to the

center line across the body, as seen in plan view. Similarly the two cutting blades are finished with their working portion finished at an angle of 10 deg. with their bodies (made from $\frac{3}{4}$ by $1\frac{1}{2}$ steel) and their cutting edges coincide with the front edge of the tangential slots in which they are secured. This position gives the tools free cutting action with a minimum of side clearance.

The two cutting tools divide the work of trepanning. The round-nose tool at the left in the assembly view has a cutting blade $\frac{3}{8}$ in. thick and is set down $\frac{1}{32}$ in. lower than the finishing

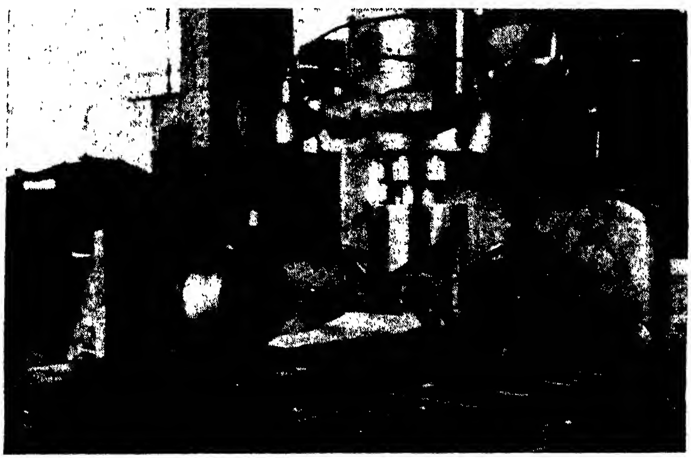


FIG. 34.—Another type of trepanning tool for similar work.

blade to rough out the cut ahead. The finishing tool (at the right in the assembly view) is formed with a square nose $\frac{1}{2}$ in. thick and with the balance of the blade reduced to a thickness of $\frac{3}{8}$ in. It thus has $\frac{1}{32}$ in. on a side to finish out behind the roughing cut.

The cutting tools project approximately 6 in. below the body of the holder proper. That is, they follow about $\frac{3}{4}$ in. after the pilot which is guided in a $2\frac{1}{2}$-in. hole bored in a preliminary operation through the rod end.

The tools are properly spaced in the head at the right radius according to the side of the rod opening to be trepanned, by means of liner blocks shown in detail in the drawing. These liners are arranged in sets ranging from $\frac{1}{8}$ to $\frac{3}{4}$ in. thick and are provided with a shoulder at the upper end so that they may be

slipped into the slots and retained therein without dropping out of place. Safety set screws clamp the liners and tools securely in place.

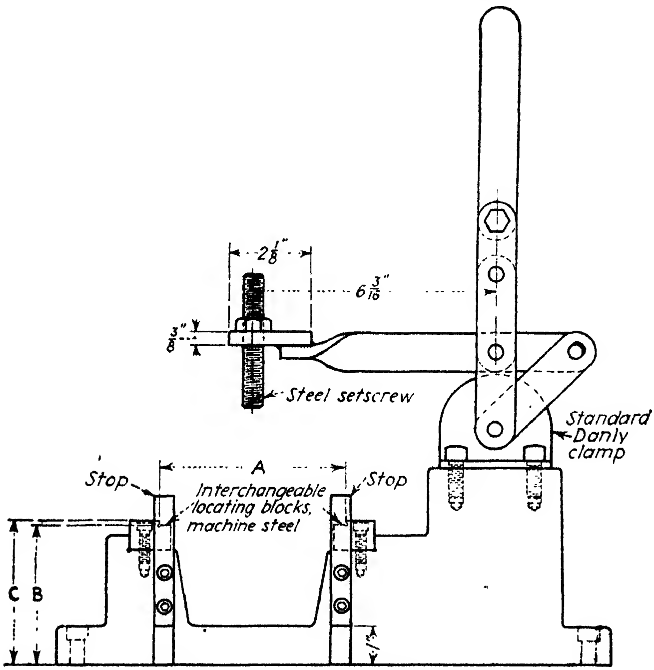
Another method of doing this same job is shown in Fig. 34. This is a true trepanning tool while the other might better be

FIG. 35.—An improvised single-point boring machine.

called a "sweep tool." Although the piece shown on the rod has a pilot hole drilled in it, no pilot is shown on the tool in the machine. This type of tool requires a very rigid machine as shown. It is also advisable to grind the cutting lips at an angle instead of square as this tends to hold the tool central during the cutting operation.

Improvised Single-point Borer.—Increased requirements for bearings by the Dodge Manufacturing Company demanded additional precision boring equipment. Since a new machine could not be obtained in time to meet the production schedule, C. A. Bloom and Merl Harkless built one of their own that proved adequate for the job.

A secondhand No. 65 Heald internal grinder was stripped of its headstock and used as the base of the boring machine (Fig. 35). A special ball-bearing spindle that operates at 1,200 r.p.m. was then added. This spindle, as well as the feed mechanism, was driven through V belts by a 5-hp. motor running at 1,800 r.p.m. Although the standard Heald table was retained on this machine,



Note: Make dimensions A, B and C to suit work

FIG. 36.—Details of the clamping fixture used.

it was necessary to reverse the feed mechanism and provide longer trip arms. The feed unit was set to provide a feed rate of 0.011 in. per revolution.

With the table trip arms properly adjusted, the machine then had an automatic cycle in which the work advanced over the boring bar and then returned. The carbide tip in the boring bar rough-bores the bearings when the table is fed toward the headstock, and finish-bores while the table is being returned to its original position. Experience has shown that the boring bar springs just enough during the rough-boring operation to leave stock for a light finishing cut.

For precision boring the upper and lower babbitted liners for Dodge "Sleevoil" bearings, a fixture like that shown in Fig. 36 is bolted to a riser block on the table of the machine. This is the fixture shown in use in the other illustration. By interchanging the locating blocks on this fixture, liners for $1\frac{7}{16}$ to $3\frac{15}{16}$ in. bearings can be accurately located for boring. When boring and facing operations are to be performed on babbitted plain rigid pillow blocks, an entirely different work-holding fixture is used. The operator finish-bores 20 to 25 liners per hour.

VERTICAL BORING MILLS

Vertical Boring Mill Work.—The vertical boring and turning mill and similar machines cut continuously—assuming the work

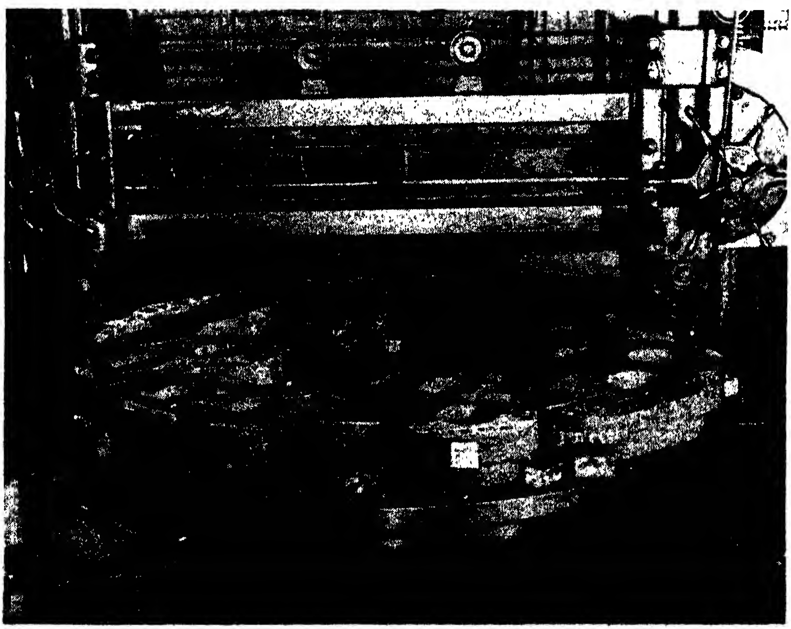


FIG. 37.—Facing large crankshaft webs on a vertical boring mill.

has no interrupted surfaces—and no time is lost in return strokes of cutting tools or work, as with reciprocating machines.

In many cases there is a choice of a number of ways of surfacing certain classes of work. Thus it may be of a kind where the vertical boring mill will handle it, or a slab-type miller, or a

planer of conventional design, or in some instances a big surface grinder may seem to be indicated, all depending upon the exact kind of job that is to be accomplished. Perhaps a shaper is best for the purpose if of sufficient capacity.

The job in Fig. 37 shows a lot of big crankshaft webs for marine engines as built at Joshua Hendy's in large numbers. There are six of these webs for every shaft, and each weighs 1,800 lb., the total weight of the assembled crankshaft being 16 tons. Eight webs are placed on the table of the big boring mill and simultaneously faced as a single unit as there is practically no cutting time lost between adjacent webs. The economy of time and effort effected by this method is obvious.

A striking view of the shaft on the shrinking stand following mounting and cooling of webs in shown in Fig. 38. This is a job in which teamwork is very necessary.

Before these shafts are completed, the parts used in them are placed in a stock pile adjacent to the shaft-assembling department. These parts are crank pins, journal pins, thrust shafts, and webs. Special clamping devices have been developed for handling the webs, which are lifted and moved into the heating tanks in sets of two. A 10-ton overhead crane does all handling and assembling, lifting, and placing. The heating tanks, filled with a special heat-resistant oil, are raised to 550 deg. F., and the webs are immersed in the oil for a period of three hours. This expands them so they will slide on the shaft section easily.

While the webs are being heated, journal pins, crankpins, and thrust shaft are placed in position on the shrinking stand and height blocks. Journal pins and thrust shaft are held by the shrinking stand in alignment to an average of 0.005-in. tolerance. Allowable tolerance before finish-turning is 0.010. The holding bases of the stand are keyed to the bedplate to assure this accuracy of alignment.

Crankpins are completely finished when brought to the shrinking stands. Journal pins and thrust shaft are semifinished to a 0.050 tolerance, to be finished in the lathe, following shaft assembly. One secret of successful web assembly is to have the webs in balanced relationship, despite the fact that they are not absolutely parallel.

When the heating process has been completed, the crane hoists a single web and carries it to the shrinking stand and, as the web

is brought opposite the first journal, two men with a bar slide it onto the pin. A jack is placed under the end of the web, set at the approximate height to give it the exact 120-deg. angle in relationship to the other webs. The crankpin is then lifted and brought into position, and again the men slide it into position.

FIG. 38.—Putting the crankshaft together on the assembly stand.

Then the crane returns for the second web. This is brought into position as before. The stands on the shrinking stand move longitudinally to permit entrance of the web. As soon as it is slid onto the crank pin, the next journal pin is slid onto the other end of the web and the first pair are then in place. Height blocks are brought over and placed under the crankpin to assure exact position, and the jack is removed.

The same operation is then followed with each of the two remaining sets of webs. A 7-min. average of time is taken for

the assembly of each set of webs. Shrinking occurs within 30 min. after the web is put in place. The now assembled shaft is left to cool for 12 hr.

Webs are placed on the low-pressure section of the shaft in one operation and on the medium and high-pressure section in a

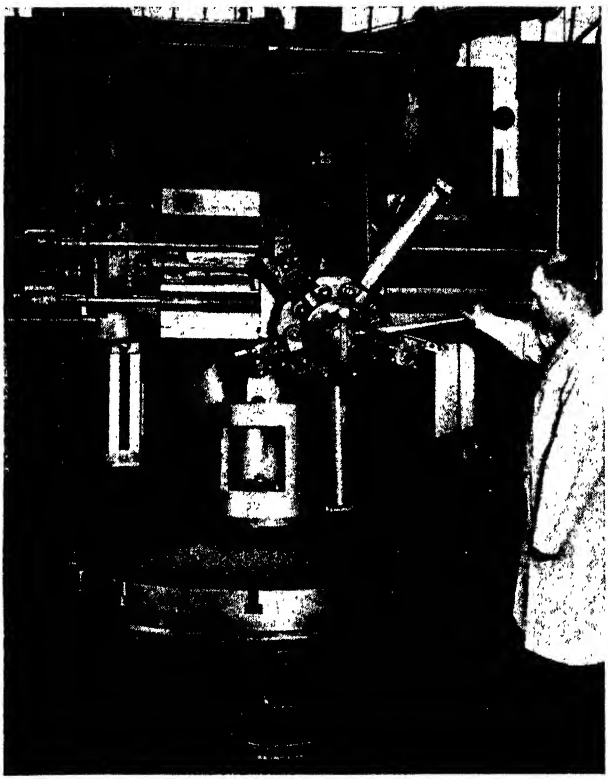


FIG. 39.—Turning a taper on a vertical turret lathe.

second operation. Next, dowel holes are drilled by a special drill that has been developed—a portable line reamer, which bores the dowel holes in position on the shaft. There are two inside and two outside dowels on each set of webs, and the webs are thus drilled in sets of two. Following this, the webs are tapped for Allen screws.

The next operation is the cutting of the keyways for eccentrics. A portable keyway miller, another development here, is placed on

the shaft as an improvement on the old method of moving the shaft to the miller.

Following the cutting of the keyways, the shaft, now in two major parts, is brought together on a stand. A portable line reamer is used to finish the flange reaming. This portable line reamer is another of the Hendy company's improvements in quick assembly of shafts.

When the flanges are bolted together and the jacks are installed between the webs to hold them in true alignment, the entire shaft is moved to the finishing department. Counterweights are placed in the webs, and the shaft is given its finish lathe work.

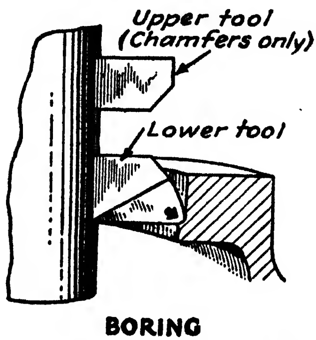


FIG. 40.—Combining tool cutting edges to save time.

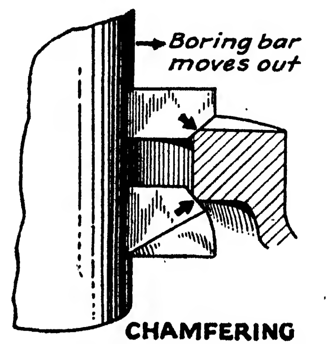


FIG. 41.—How the tools are used.

The vertical boring mill shown in Fig. 39 has a turret on the ram and may carry numerous cutting tools for boring, turning outside diameters, facing, and the like. As shown, the mill is set up for machining a piece requiring facing at the ends, turning of the outside taper, and other operations. Sometimes, where repetition work is being handled in quantity, a locating pin or gage is used to fix the ram at a definite angle for producing the same taper on the surface and allowing quick setting of the tool to the exact angle necessary for the lot of work. This makes an easy and accurate way of machining the piece shown.

Sometimes a link motion is attached to the upper end of the ram to swing the tool through an arc as it is fed down, for the purpose of producing a curved surface on the work.

Tooling That Saves Time.—A boring job at the Allison engine shop had to be chamfered at each end of the bore. This originally used three tools but has now been merged into one operation by

combined tooling as suggested by Merrill Hamilton. The tools are shown in Fig. 40. The lower tool has two cutting edges, the point with the arrowhead on it and the chamfer or beveled edge above it.

The first operation bores the hole, as in Fig. 40. When this has been done, the boring bar is positioned as in Fig. 41 which presents two chamfering tools to the work and both upper and

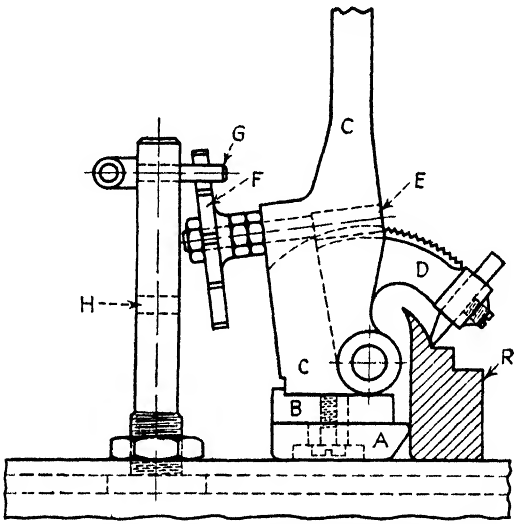


FIG. 42. An unusual application of the star feed to form turning.

lower edges are chamfered at the same time. This combination takes less time and saves changing tools or swinging the turret on the ram of the boring mill.

Using Star Feed on a Vertical Boring Mill Job.—An unusual application of the star feed is seen in Fig. 42 which shows how it was applied to a vertical boring mill in the shop of the Richmond Foundry and Machine Co. in turning bronze rings for 60-in. searchlights. Five rings were made from each casting which weighed about 440 lb. These rings were first turned to a rough approximation of the desired shape and cut off from the main casting. They were then centered on the boring mill table by a ring *A*, Fig. 42, and clamped on the outside. On top of the centering ring is another ring *B* on which the tool-carrying holder *C* rides as the work and the ring are turned by the boring mill

table. This holder C is fastened in the toolhead on the boring mill ram.

This tool holder carries tool arm D which has a segment of a worm on the upper side as shown and swings as indicated. The tool holder also carries the worm E, driven by the star wheel F. Remembering that the tool holder remains stationary, supported by the ring B which revolves under it, it is easy to see how the pin G, fastened in the upright that moves with the

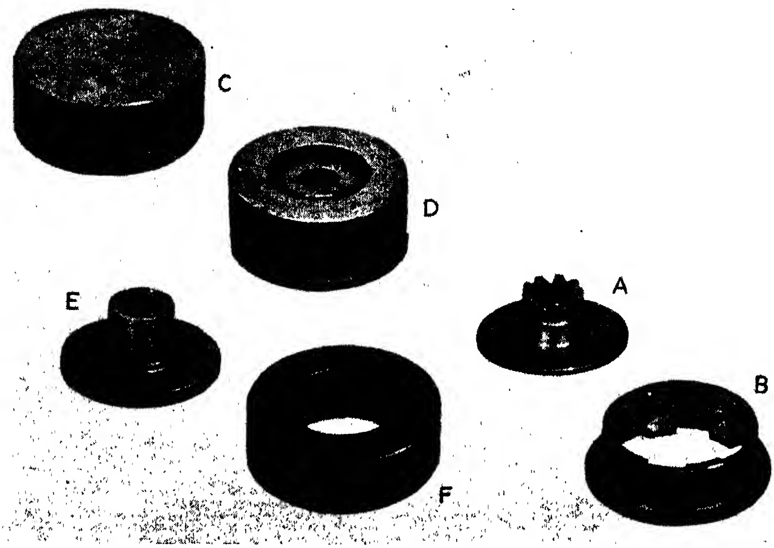


Fig. 43.—How much valuable steel was saved by trepanning.

revolving table, strikes the star wheel at every revolution and moves it one notch.

This turning of the star wheel turns the worm and moves the cutting tool across the edge of the ring R, turning the form shown. When the tool has been fed its full stroke in one direction, the pin G moves to the lower hole H. This then strikes the star wheel on the lower side and turns it in the opposite direction.

This same method can be used for turning concave surfaces by pivoting the tool arm above the cutting tool instead of below it as in this case.

Saving Valuable Material by Trepanning.—The methods shown not only saved about 50 per cent of valuable 4130 steel but also enabled the Kuhlmann and Harmon machine shop in

Wichita, Kan., to utilize a Rockford drill press for the work instead of tying up much more expensive machines. The tools and method, devised by two foremen, L. A. Fuller and Allen White, are excellent examples of practical ability.

Two finished parts are shown at *A* and *B* in Fig. 43. These were formerly made from separate pieces of 4130 steel, each

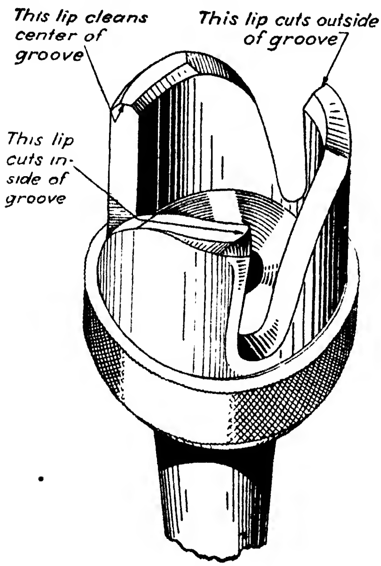


FIG. 44.—Three-lipped trepanning tool used in Fig. 43.

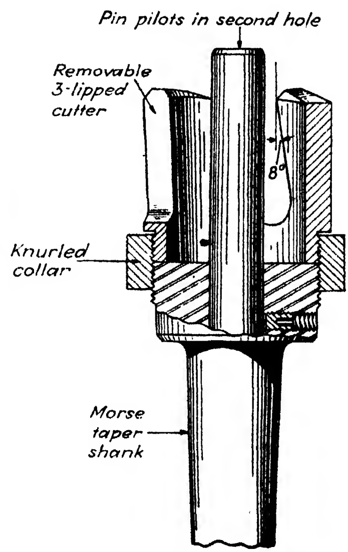


FIG. 45. Sectional view to show how parts were held together.

weighing over 7 lb. By their method both pieces are made from a single blank, shown at *C*. This blank is first cut with a parting tool and then trepanned as at *D*, giving the two pieces *E* and *F* from which the finished parts are finally made.

The blanks are first faced at one end and then grooved to the proper depth and a hole drilled for the pilot of the trepanning tool. Experiments proved that a three-lipped trepanning tool was better than one with two teeth, or cutters. Figure 44 shows how these were made. The three-lipped cutters were held to the shank by the knurled collar shown in the sectional view. Figure 45 shows how the pilot or guide was held in place. The arrangement of the cutting edges is also important. They divide the cut into three parts as shown. One cuts the outside, one the center, and the third finishes the inside of the groove.

With the removable cutters, it is an easy matter to replace a dull cutter with one freshly sharpened.

The cutters were made from the same 4130 steel as the work, with Tool Weld welded on the cutting edges. Stellite would probably answer the purpose as well, but high-speed steel did not prove satisfactory. The cut is $\frac{3}{8}$ in. wide and $1\frac{5}{16}$ in. deep to separate the two pieces. The average time was $7\frac{1}{2}$ min. and over 1,000 cuts per grind were secured with this tool.

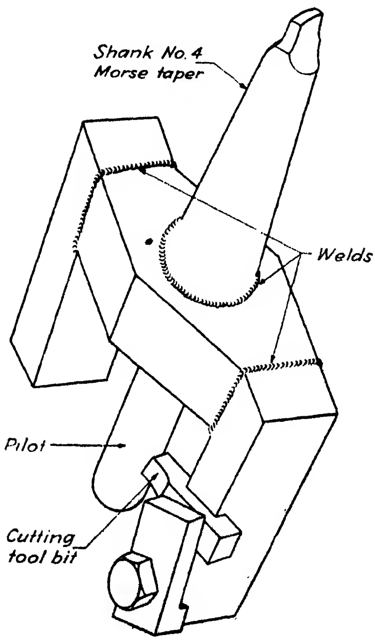


FIG. 46.—How the sweep tool was built up by welding.

The outside of the ring was also machined on a drill press using the sweep tool shown in Fig. 46. This tool was made up by welding a No. 4 Morse taper shank to the cross member shown, this in turn being welded to the two arms that carry the cutting tools. The pilot guides the tools while at work on the piece. Figure 46 shows only the facing tool in position, but the location of the other can be seen from the sectional view (Fig. 47). The work is held in place by the nut that goes inside it and bears on the collar at the bottom. The upper end of the threaded piece which acts as a clamp is flattened on two sides to provide for a wrench used in tightening the work to the fixture.

This same tooling could be used for separating the two parts if it seemed best to do this work on a turret or engine lathe. In fact, the whole operation could be done on a turret with very similar tooling. Knowing how to use trepanning tools for cutting out solid pieces and realizing that sweep tools also have their place in many shops can save much valuable time and permit the use of machines not usually employed.

Large Machine Tools.—The Consolidated Machine Tool Corp. is one of the few builders of very large machine tools in this

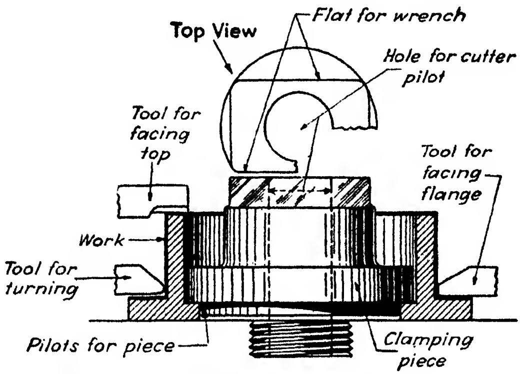


FIG. 47.—Details of a holding fixture and tools at work.

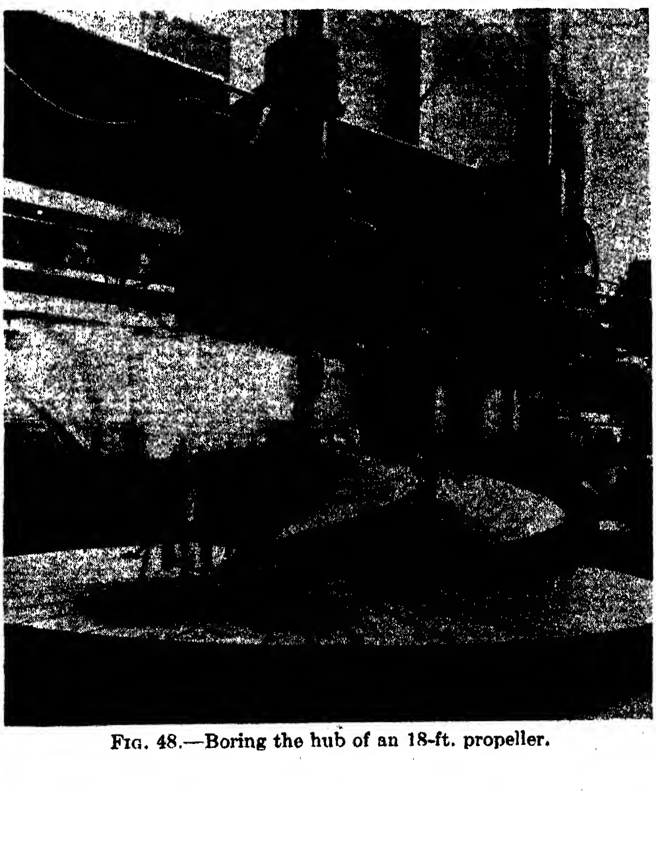


FIG. 48.—Boring the hub of an 18-ft. propeller.

country. Figures 48 and 49 will give an idea of some of them. In Fig. 48 an 18-ft. propeller for one of the large naval vessels is being bored on a boring mill having a 25-ft. table. Although not noticeable in the illustration, the boring bar or ram is set at an angle to give the proper taper in the hub. The way in

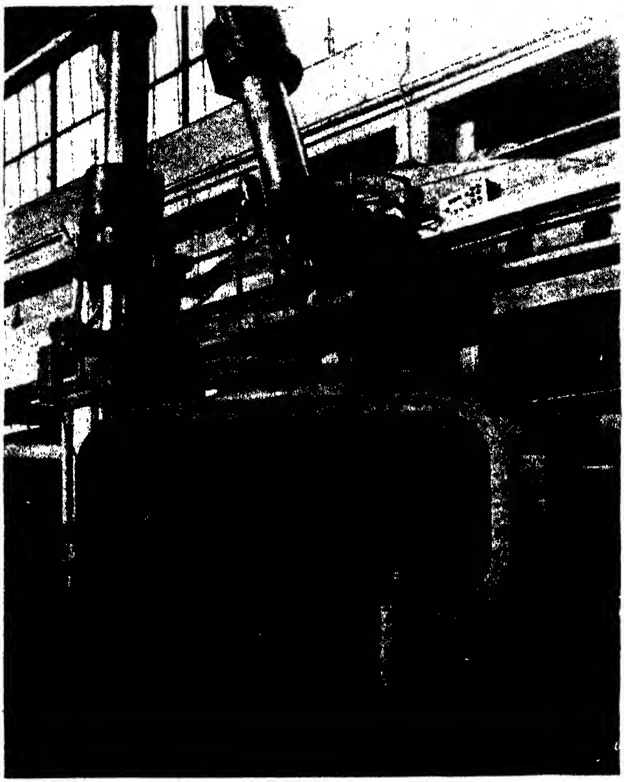


FIG. 49.--A 14-ft. Consolidated boring mill at work on a large turbine housing.

which the propeller is held may be seen, as well as the position of the operator in the cage or platform that surrounds the tool bar or ram.

Part of a turbine housing is being machined on a 14-ft. boring mill in Fig. 49. Here one ram is tilted at a very noticeable angle for boring the tapered opening. This machine also provides a platform for the operator over the work which enables him to see just what is being done by the cutting tool. The methods

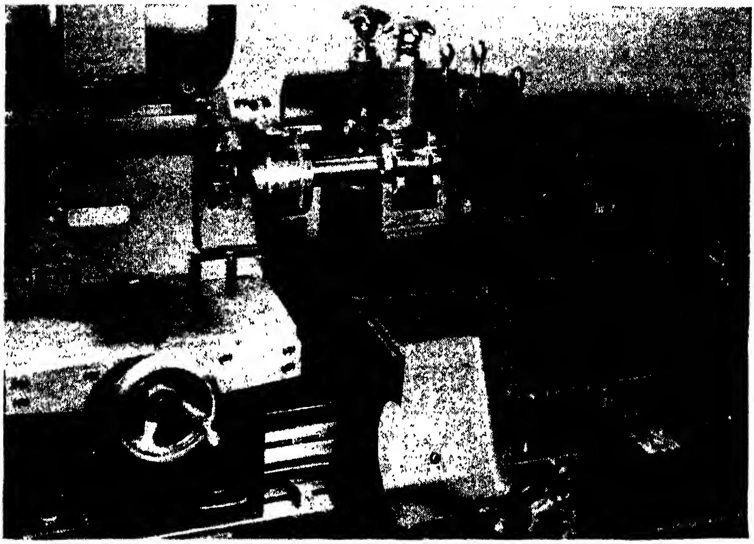


FIG. 50.—Two-spindle Ex-Cell-O single-point boring machine at work on airplane-engine connecting rod.

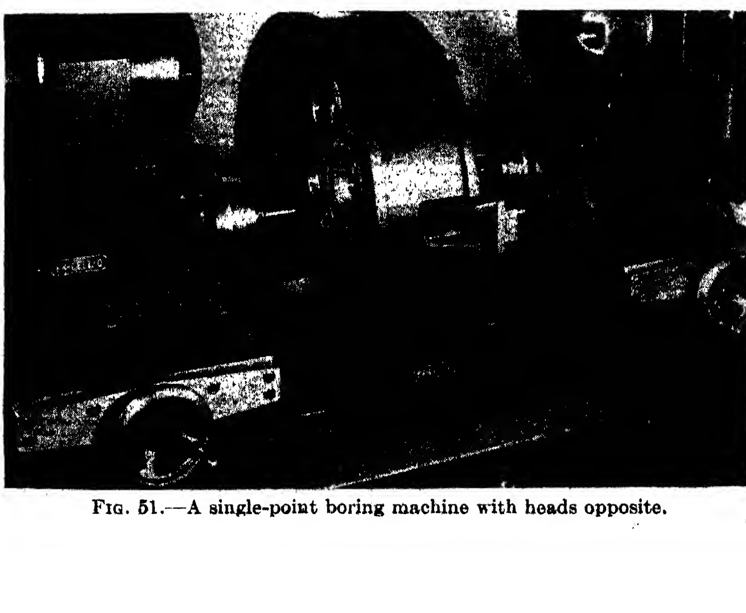


FIG. 51.—A single-point boring machine with heads opposite.

used in locating and clamping a large casting of this kind are also shown.

Single-point Boring.—Two interesting applications of the single-point boring machine method are seen in Figs. 50 and 51. In the first a two-spindle machine is used to finish-bore the bearings in the ends of a master rod for an airplane radial engine. The boring spindles are set at the correct center distance and are of course parallel. This acts as a single-purpose machine but would not require new heads should the center distance be changed. The heads could be respaced.

Another machine is seen in Fig. 51 where the heads are opposite each other and the work is held in a special fixture between them. Here both the work and the spindle heads are moved to reach the different holes to be bored. Both these machines are by the Ex-Cell-O Company.

CHAPTER V

LATHE WORK—TURNING

Lathe work covers a wide variety of machining of many different kinds. Generally speaking, it refers to work revolved in a machine where the operation is done by single-point tools that are stationary except for being fed against the work to remove chips from it. The engine or screw-cutting lathe is probably the most versatile machine tool yet devised as it can turn, bore, cut tapers and threads, and can, with a few attachments, drill and mill if neither of those machines is available. It takes two distinct kinds of work: that held between centers and that held in the chuck or on the faceplate, usually for some boring operation. It has well been called the "backbone" of the small shop.

Formerly depending on the skill of the machinist for the quality of the work both as to size and to finish, many lathes now have automatic features that have removed the necessity for much of the skill formerly necessary. Precision stops for both longitudinal and cross feeds, multiple tool posts, and other features put it in the semi-automatic class in some cases. These, however, are useful only in comparatively small work, and the old-time machinist, or his counterpart, still must exercise skill in handling work of large dimensions. Examples of this will be shown later in this chapter.

Turret lathes, which began as small hand-screw machines for very small work, have grown both in size and in versatility and now handle much work that was formerly done on the engine lathe. With the modern standardization of tooling for turret lathes it is possible to utilize them on much smaller quantities than formerly. Then it was necessary to have special tools for each job. Now it is comparatively easy to set up a great variety of jobs with the standard tools that accompany the turret lathe. It is still a question of the quantity to be made as to which type of lathe to use. Standard tooling has made it possible

to set up and machine a new job in much less time than formerly and at much lower cost for tools and equipment. This has made the turret lathe more of a competitor of the engine lathe than ever before.

A variety of jobs of different kinds will be shown, some of them unusual applications of the engine lathe as part of the war effort.

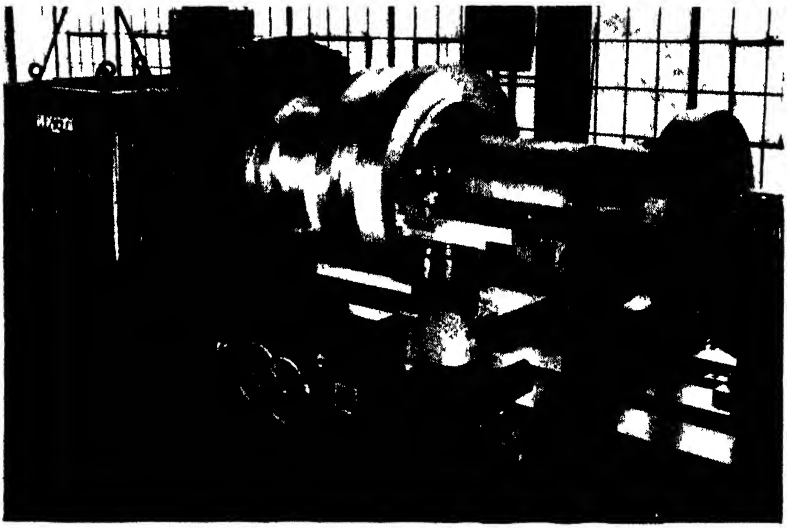


FIG. 1.—Heavy lathe work in the Mesta shops.

Heavy Engine Lathe Work.—Two excellent examples of heavy work being done on the engine lathe are shown in Figs. 1 and 2. These are in the shops of the Mesta Machine Co., which also built the lathes being used. The first shows the turning of the rotor shaft for a large turbine generator. These shafts are forged from ingots poured in the open-hearth department of the company, and have been furnished by them for many of the world's largest power plants, such as Boulder Dam and Bonneville. As will be seen, this is a very large lathe. The size of the work and the lathe can be estimated by comparing them with the machinist in front.

It will be noted that the lathe has three wide, flat ways and that the tailstock bears on the back and center ways and not on the front way. All the geared head mechanism is contained in

the cubical headstock, and a separate motor provides power for the carriage feed. All movements can be controlled from the push-button panel seen lying on the lathe carriage.

A similar lathe is shown in Fig. 2 with two tool posts in action. This lathe has two carriages, each motor driven, and is at work on a turbine shaft for the Grand Coulee dam powerhouse. It gives an even better idea of the size of the lathes than the other.

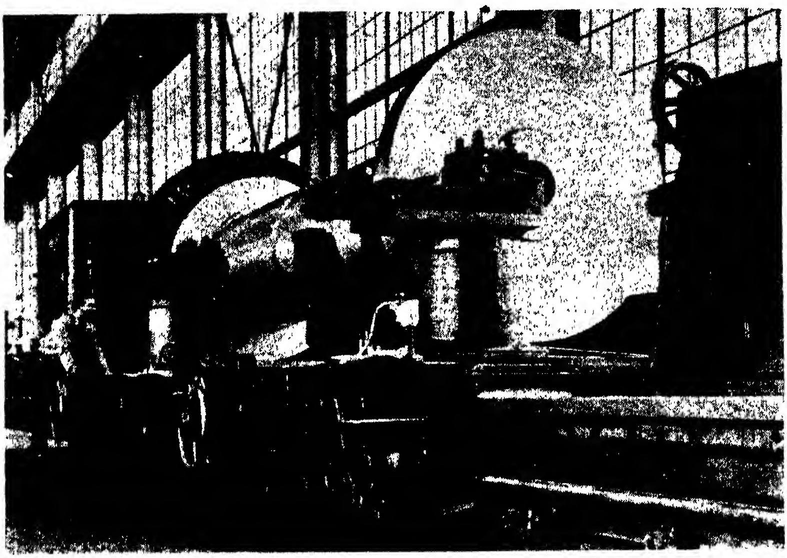


FIG. 2.—Another big lathe job in the Mesta shops.

Another Heavy Duty Lathe.—Engine lathes used in the average shop are small as compared with those needed for large propeller shafts for steamships and in the manufacture of big naval guns. A recent lathe of this type, by one of the oldest machine builders in this country, is shown in Fig. 2*a*. This is a late machine of the Mackintosh-Hemphill Co., Pittsburgh, Pa., built for crankshaft and other battleship shafting. Headstock, carriage and both the bed and its ways are of modern design.

This lathe is shown turning both a plain propeller shaft in Fig. 2*a* and a crankshaft in Fig. 2*b*. General size can be judged by the men. Faceplates run up to 72 in. in diameter and are built to take 85 ft. between centers. Roughing cuts 2 in. deep with a feed of 1/4 in. per revolution of the work can be taken when necessary.

The heavy carriage is supported by three flat ways as seen in Fig 2b This also shows a special tool post as used to turn

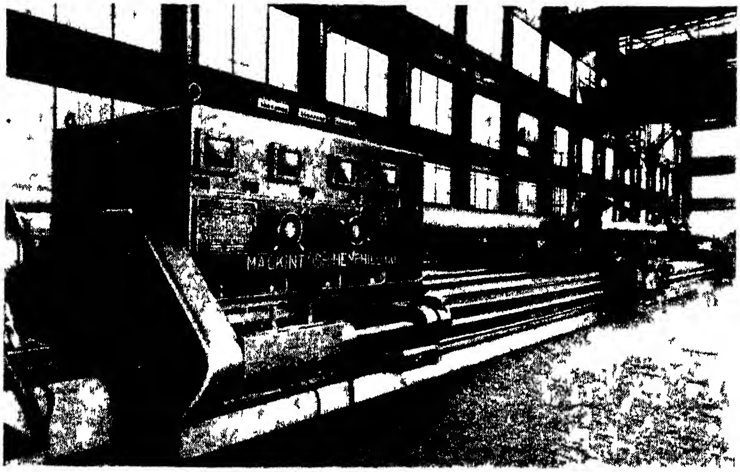


Fig 2a —Turning a long propeller shaft

Fig 2b —Turning a crankshaft

bearings between the crankcheeks. The tool post at the left has been removed to show the circulor base that supports it. The carriage is fed by a heavy feed screw which can be seen

between the front and middle ways in Fig. 2*b*. This is driven by an auxiliary motor at the tail end of the lathe. The lead screw for thread cutting is on the front of the bed. Both illustrations show two carriages. The driving motor can be controlled by levers on each carriage. Force feed lubrication includes all gear-meshing points as well as bearings, and the oil pump is interlocked with the headstock motor to ensure oil flow whenever the lathe is running.

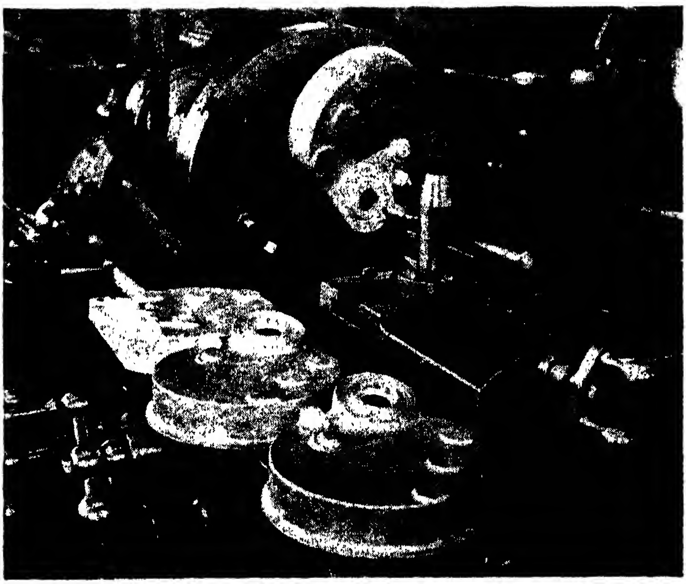


Fig. 3.—Turning work that is not concentric.

Eccentric Faceplate Fixture.—An interesting adaptation of the engine lathe for special work is shown in Fig. 3. The pieces shown have a boss that must be faced and bored at the proper location and at the right angle to the back of the piece. This makes a good example of the way in which the lathe can be used for unusual work with a little ingenuity on the part of the operator.

The back of the piece is first faced smooth and square, the piece being held in any sort of lathe chuck. The piece is then located on the fixture that is bolted to the faceplate of the lathe. This fixture is bored to receive the back of the work and hold it at such an angle that the face of the boss will be bored square

with the center of the lathe. This angle on the surface that holds the work can be clearly seen in the holding fixture.

With the work held at the proper angle and with the boss brought in line with lathe centers, the hole in the boss as well as its face can be machined at the desired angle.

The work is hollow and is held against a curved surface on the fixture by the screws shown on the face of the fixture. With the work slipped over the holding surface and the screws tightened, the work is held firmly at the right angle and with the hole in the correct position for boring. When suitable fixtures can be made, as in this case, the engine lathe adapts itself to economical production unless the quantity needed will warrant the building of a special machine. Because of the comparatively low cost of the engine lathe, it is necessary for any special machine to have a great output to make it economical when all the costs are considered.

Precision Boring in the Lathe.—Where work is bored in fixtures, as is usually the case where even small quantities are made, the accuracy secured depends on the fixture and not on the machine on which the fixture is mounted or on the spindle that drives the boring bar. It is therefore possible to do accurate boring on machines that simply act as a base for the fixtures and supply power to the boring bars, even though the machines themselves are worn and are not accurate in themselves. A realization of this would save purchasing expensive boring machines when they were not necessary.

An excellent example of boring on old machines is seen in Fig. 4 where a buffer housing for a gun carriage is being bored on an old 60-in. Niles lathe. With two I beams as a base, the fixture shown was built up, largely by welding, and mounted on the lathe carriage in such a way as to bring the hole to be bored in approximate alignment with the lathe spindle.

A boring bar that fitted accurately in the bearings of the fixture was driven from the lathe spindle through a universal joint so that perfect alignment between spindles was unnecessary. The outer end of the hollow boring bar was fitted with a connection to receive a coolant through the hose shown. The coolant, under 5-lb. pressure, was fed to a point just ahead of the high-speed bit in the bar and $4\frac{1}{4}$ in. was bored at 26 r.p.m. with a feed of 0.028 in. per revolution. The work was fed over

the bar using the regular carriage feed gearing. The work was just as satisfactory as though it had been done on a special boring machine.

Several good examples of smaller boring jobs are shown in the illustrations that follow. Here again the engine lathe serves as a boring machine on work that is usually done on a special type of machine sometimes known as a "diamond borer." These special

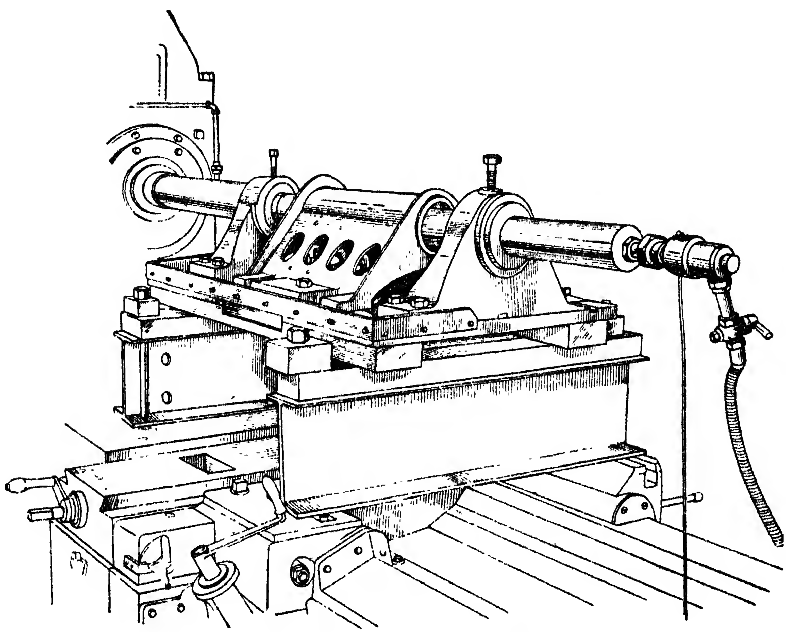


FIG. 4.—Precision work on a gun carriage in an old lathe.

machines are economical on large production, their accuracy depending on the spindle bearings and the alignment with the work-holding fixtures. The jobs shown were done on a production basis by G. M. Evans, then manager of the Kelvinator Company, and the work was the building of the compressor units of the refrigerating machinery.

All the fixtures were based on the use of the V block, a true-running mandrel, and a surface plate. The whole setup was very simple and could be used by semiskilled workers. It also utilized the engine lathe, care being taken to ensure the accuracy of the bearings and the ways of the lathe.

Pinholes in the compressor pistons were bored in the V-block fixture shown in Fig. 5 within a tolerance of 0.0002 in. between the go and not-go gages. This engine lathe was fitted with a head at each end. V block 1 locates piston 2, this being held by the formed clamp 3. A stop under the piston locates it for height. To locate the piston in the fixture a loose fitting mandrel is put through the rough-bored hole and two aligning fingers,

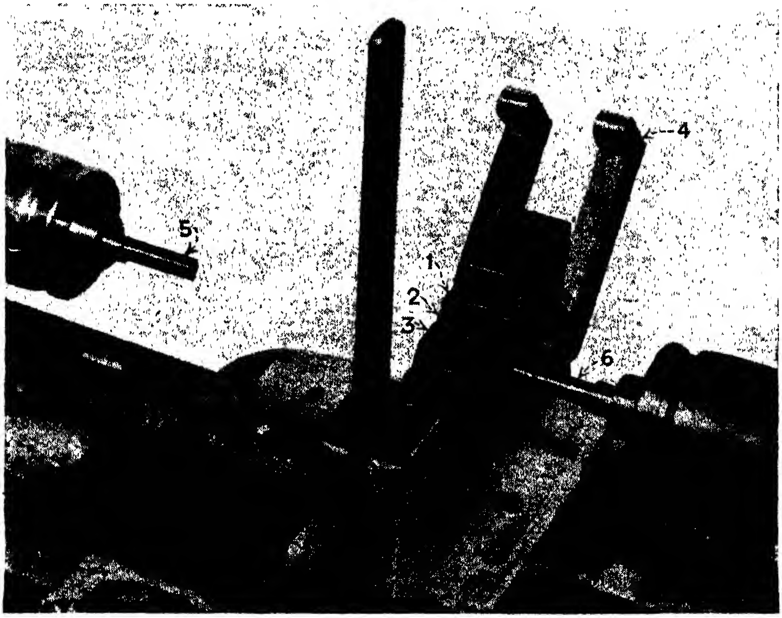


FIG. 5.—Fixture for boring pistons.

4, swing down into contact with the mandrel to line the piston true with the ways of the lathe.

After locking the piston in place, the first cut is taken by cutter 5 in the left-hand head of the lathe, and the bore is finished by the cutter in the other head, as shown at 6.

The use of the mandrel and V block in checking the alignment is seen in Fig. 6. Here the piston is again held in a V block that is square with the surface plate. A close fitting mandrel is placed in the bored holes and both ends of the mandrel are checked with the dial indicator shown. With a 7-in. mandrel and an indicator reading to tens of thousands, the accuracy can be determined easily.

Another accurate boring job is seen in Fig 7 where two bores must be kept parallel and also square with the crankshaft bearings A close fitting mandrel 2 is wrung through the crankshaft bearings and positioned in V blocks 3 and 4 which have been lined up so as to be square with the travel of the lathe

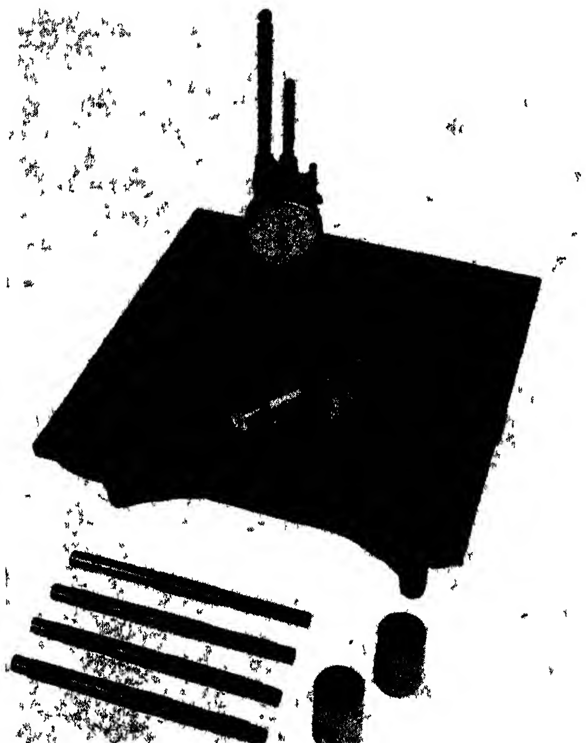


Fig 6—Checking squareness of piston pinhole in the piston

carriage Clamps at 5 and 6 hold the mandrel in the V blocks For making the first bore, the cylinder block is located against the stop 7 The wedge clamp 8 holds the cylinder against this stop but exerts no pressure against the cylinder walls.

Plate 9 carries a hardened button which locates the cylinder on a surface that is milled parallel with the crankshaft bore. This button is just below the center of boring bar 12 Clamp 10 has a spring tension against the button and so does not tend to distort the cylinder bore. This is important as metals distort

more than many realize. This setup gives the operator a clear view of the work at all times. The cylinder bore was 1.25 in., and the cutter ran 1,700 r.p.m., giving a cutting speed of 556 ft. per minute. The feed was 0.0015 in. per revolution.

For boring the other cylinder, the casting was moved to the left and positioned against the long end of stop 7. This stop was simply reversed and the cylinder located by the other end for the second bore.

FIG. 7.—Holding the cylinder to ensure that the shaft bearing will be square with the bore.

It is interesting to note that Mr. Evans preferred a used lathe for work of this kind because any distortion that might occur from age had already occurred. The beds are of course planed or ground perfectly true and scraped, if necessary, before being used on this accurate work. Great care is also taken to use the best spindle that can be obtained.

In using this method, it is very important that the V blocks be square with the ways of the lathe bed. Figure 8 shows how this was checked. A 36-in. steel scale, 1, is clamped to the carriage and the carriage moved past a dial indicator shown at 5. This is a ten-thousandth indicator. When the scale shows the

same reading at each end, it is clamped firmly in place. V blocks 2 and 3 are then mounted on the surface plate that forms the base of the fixture and are adjusted so that mandrel 4 and indicator 5 are at right angles when the indicator is swung to the other end of the scale. It will be noted that the indicator is held on an arm clamped to the mandrel near figure 4. Plate 6 has a ball that acts as a stop for the end of the mandrel.

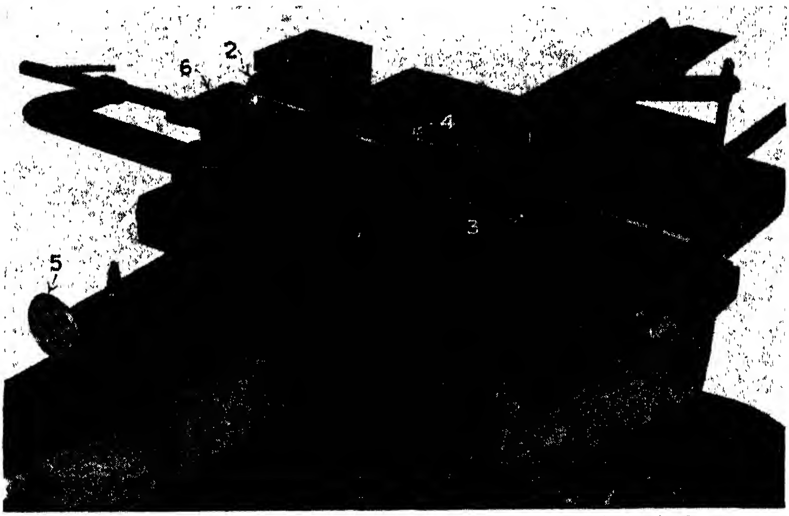


FIG. 8.—Squaring V block with the ways of a lathe bed.

When the blocks are square by this test, they can be clamped to the surface plate with the assurance that they are square with the ways of the bed.

Automatic Diameter Turning in an Engine Lathe.—The St. Charles Works of the Canadian Car and Foundry Co. make strut cylinders for Hurricanes on an engine lathe, securing the different diameters by hand adjustment of the tool slide for each diameter. Formerly, this took about 4 hr. for each job.

By using a former or guide for the cross slide (Fig. 9) in much the same way as we use the taper turning attachment, the time was cut to 50 min. Figure 10 shows the details of how this was done in a comparatively simple manner.

Bar *A* controlling the tool slide has an arm *B* carrying a hardened follower pin. Contact between the pin and the guide bar or templet is maintained by the two hydraulic cylinders

C and D operating through the cross bar E. Once the tool is set and the carriage feed engaged, the tool feeds along the bed, automatically cutting to the right diameter and giving the proper fillets.

The roughing cut leaves about 0.050 in. for finishing. The hydraulic cylinders control the tool for both operations. This is another and rather unusual example of contour turning in the engine lathe.

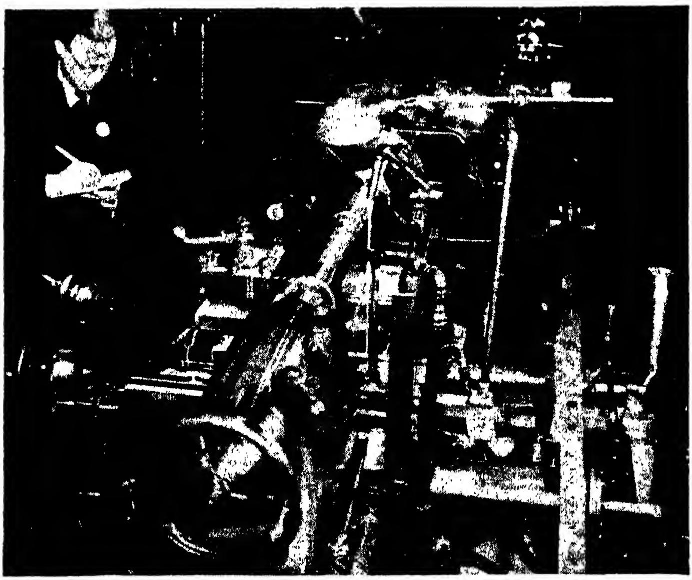


Fig. 9.—Turning desired diameters automatically.

An Awkward Lathe Job.—Turning the base of the gun mount shown in Fig. 11 is about as awkward a job as ever comes to an engine lathe. It could have been done more easily on a vertical turret lathe, had one been available, because it is easier to set such a piece on the horizontal table of a boring mill than to fasten it to the faceplate of a lathe as shown. In either case it requires special blocking or mountings to hold the work with the face in the right position for machining. In the lathe it is necessary to support the work with a crane or sling while it is being positioned on the faceplate; with the boring mill it is only necessary to lift it to the table after which it can be positioned with much less trouble.

The figure shows how the work is clamped on the angular fixture so as to bring the base square with the lathe centers or the cross slide. On account of the length of the arms of the gun mount, it is necessary to use a gap bed lathe so that the arms will swing clear as the work revolves. Once in position, it is an easy job

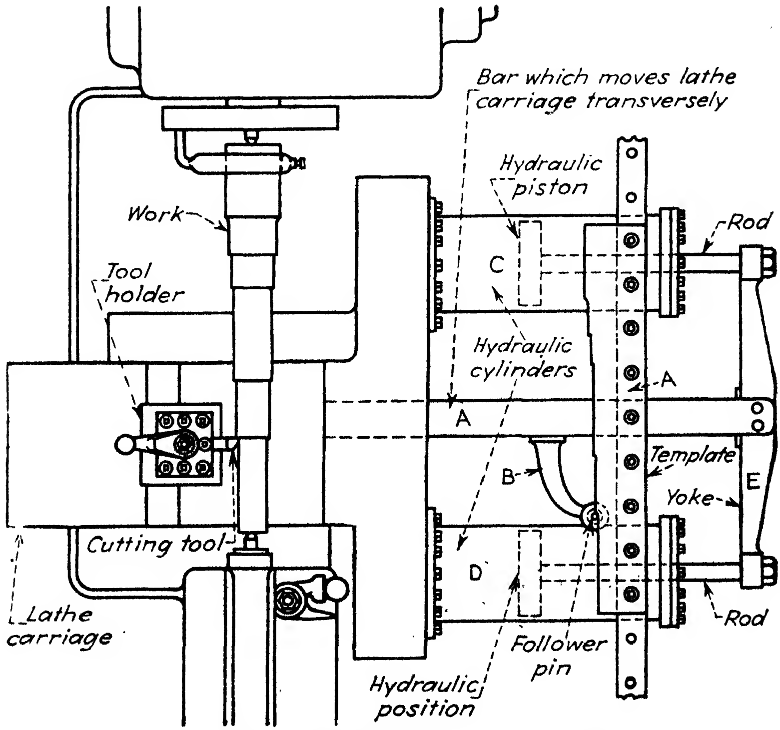


FIG. 10.—How desired diameters are controlled.

to face the base of the mount flat and square, using a raised tool post for the work.

It will be noted that a temporary fence has been built to prevent anyone from being struck by the projecting arms as the work revolves. Although not shown, it is necessary to put balance weights on the other side of the fixture to counterbalance the weight of the arms of the gun mount and secure a steady movement of the work in the lathe.

Form Turning.—Turning work to a specified form, such as a curve with a given radius, can be done in a number of ways.

Where the surfaces are small, the desired shape is frequently secured by using a "form" tool of the desired shape. This requires very careful tool grinding, and wear at any point changes the contour from the form desired. To avoid this and also to turn surfaces larger than is feasible with a formed tool, single-point tools controlled by cams or forms of the desired shape are used in a variety of ways.

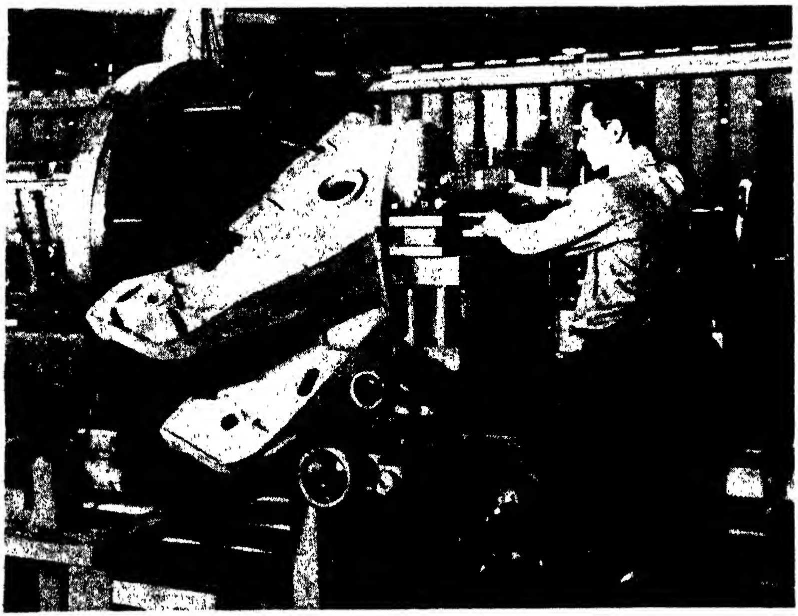


FIG. 11.—Facing the bottom of a gun mount in a gap-bed lathe.

The simplest and most common example of form turning is with the taper attachment supplied with many engine lathes. Here the movement of the tool in relation to the lathe centers is controlled by a shoe, or guide, moving along a fixed bar set at the proper angle to give the taper desired. This bar is fixed at the back of the lathe bed and moves the tool point so as to turn the taper that is wanted. The cross-feed screw is of course disconnected so as to permit the tool block to move across the bed in the carriage saddle, as the guide moves along the bar with the feed of the carriage.

Curved contours can be cut in the same way by substituting a bar or cam having the desired shape for the fixed taper bar and

by using a roller or other contact in place of the sliding shoe of the taper attachment as in Fig. 12. Where a roller is used, as in most cases, it is necessary to consider the diameter of the roller in laying out the outline of cam. The path of the curve desired must lie at the center of the roller, and the cam itself must be modified as shown by the curve drawn touching the circles that represent the cam roller. Although the curves may appear to be the same, there is enough difference so that the exact form desired will not be produced unless the diameter of the roller is taken into account.

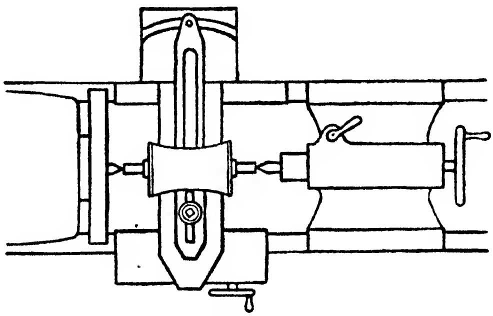


FIG. 12.—Turning a curved contour with a guide at back of lathe.

If a solid point contact is used in place of the roller, the radius of the point should be considered, although the smaller the radius the less distortion between the form and the finished work. Means should also be provided for keeping the contact between the roller, or point, and the outline of the form or cam. The most common way is to use a heavy weight on the cross slide, attached by a cord or cable running over a pulley as in Fig. 13. This is a very simple method of using a weight, which in this case is a heavy bar of steel. As will be seen, this is an improvised device, supported on the end of a box behind the lathe. The pulley shaft has no bearing except on top of the box. But this rig was doing an important job for airplane accessories during the war. Springs are also frequently used for maintaining contact between the roller and the cam. As long as contact is maintained, the method is not important.

Where the desired forms are circular, they can be secured by swinging an arm carrying the tool over the surface, with the tool point at the desired radius. One method of doing this is seen

in Fig. 14. Here the radius tool is carried in an arm pivoted beneath the center of the lathe spindle The tool-carrying arm is moved by attaching the bar shown to the lathe carriage and

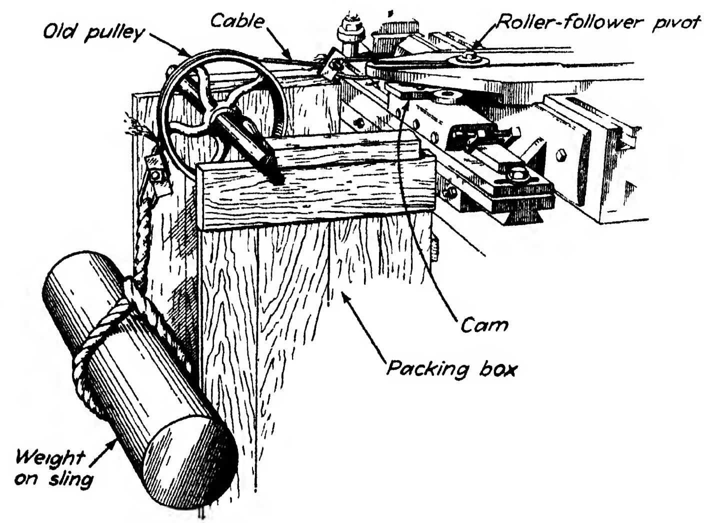


FIG. 13.—Keeping the roller in contact with the guide by a weight

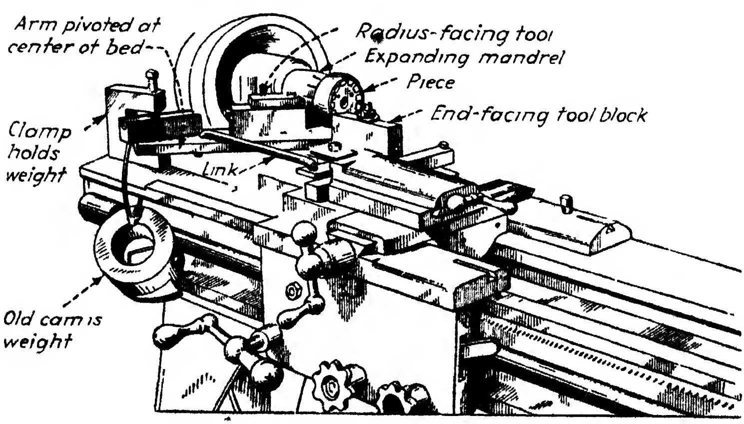


FIG. 14.—Turning a radius with the tool in a swinging arm

throwing in the carriage feed to move it to the right. This swings the arm on its pivot and forms the desired radius on the work, which is held on an expanding mandrel in the lathe spindle.

Another very ingenious way of doing this job is seen in Fig. 15, which shows a small special machine built from the differential of an old automobile. The differential case is mounted vertically on a small base casting, with one of the driving axles uppermost. This acts as the work spindle of the machine and carries an expanding mandrel for holding the work.

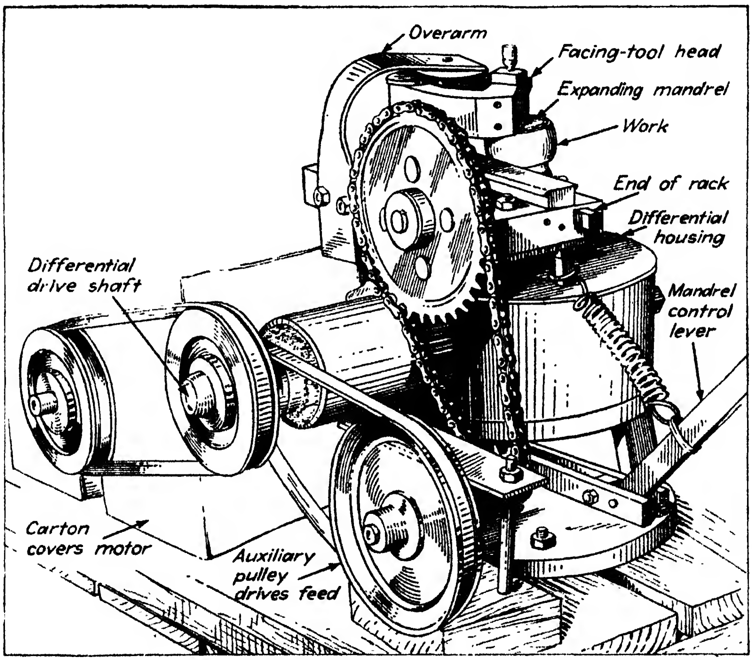


FIG. 15. - Special radius turner made from the differential of an old automobile.

Power is supplied through the drive-shaft end as seen in Fig. 15. This view also shows the way in which power is transmitted to the arms that carry the cutting tools. The inner end of the upper shaft carries a small crank which in turn drives the rack shown and moves it in both directions. This rack bar has teeth on the top and one side. These engage small gears on the shaft of the tool arms and swing them over the work after it has been put in place and the machine started on its cycle. The rack itself is driven by a small crank and connecting rod which moves it back and forth.

One of these gears, meshing with the teeth in the top of the rack, swings a tool arm which cuts the desired radius on the work.

The gear on the side of the rack swings the arm which faces off the top of the work. The piece is part of a universal joint for airplane work.

For forming surfaces at right angles to the lathe spindle, form *B* can be fastened to the lathe bed as in Fig. 16 by the

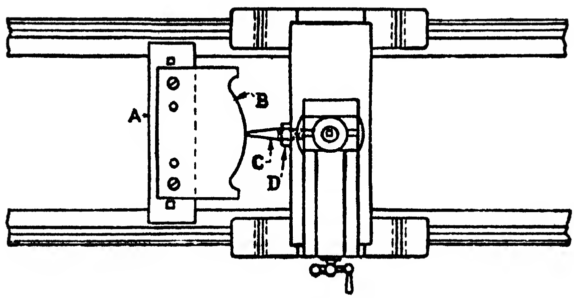


FIG. 16.—Another use of a former for guiding a lathe tool.

cross bar *A*. The pointer or guide *C* is fastened to the cross slide and locked by the nut *D*. By keeping the guide pin in contact with the form, the tool in the cross slide will reproduce the desired contour on the work held in the chuck.

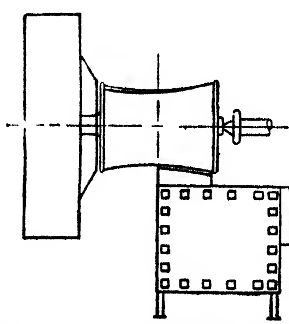


FIG. 17.—The forming of wide curved surfaces in two cuts.

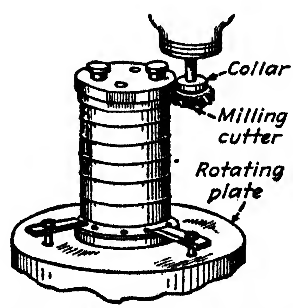


FIG. 18.—Milling an irregular shape on the end of a cylinder.

Broad-nosed form tools require considerable pressure to force them into the work. To avoid this, the work can be divided into two or more cuts. Figure 17 shows how the radius on a roller for torpedo tubes was made in two cuts at the Nordberg Manufacturing Co. on a war job. The illustration shows one tool cutting the right-hand half of the radius. The second tool, when swung into position, will cut the other half. The other

two tools cut the grooves at each end of the roller. Using two tools requires care in matching the cuts in the center.

The top plate of a marine engine cylinder was of irregular shape and was originally milled on a vertical machine as shown in Fig. 18. A guide was clamped to the top of the cylinder and a collar on the cutter spindle followed this guide plate to give the desired contour on the cylinder.

The work was then transferred to an engine lathe, as in Fig. 19, and turned instead of milled. The driving plate has a taper

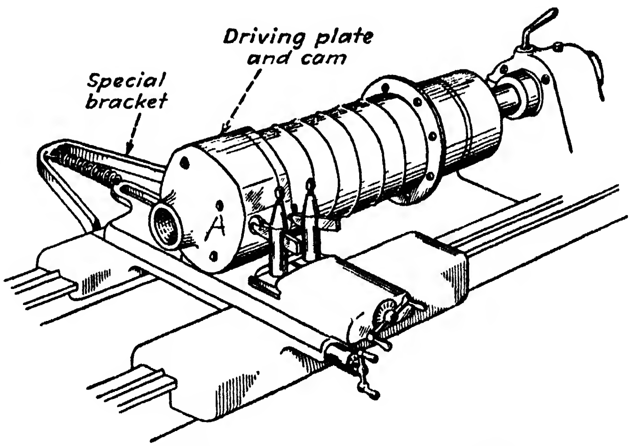


Fig. 19.—Forming the same job on a lathe by using a guide cam.

shank, not shown, and also carries a cam of the proper shape. The cross feed was disconnected, and a spring connected to a special bracket keeps the guide roller and the tool in contact with the cam and the work. One tool post carries the guide roller, the other the cutting tool. This method increased the output about 60 per cent.

Another Forming Method.—The Lockheed Co. needed a quantity of steel yokes with a spherical surface on the outside. As the usual methods failed to give the precision required for the work, S. D. McIntosh, a machinist in the plant, devised the setup shown in Fig. 20, using the rotary table shown on a milling machine. The tool slide came from another machine.

With the yoke held between centers and driven by the milling machine spindle and the rotary table centered directly under the spherical portion of the yoke, the desired accuracy was secured.

The cutting tool was also set at the center of the yoke ends, or at the same height as the centers on which the yoke turned, to give the diameter required for the spherical surface. This device secured the desired results in satisfactory time.

Machining Spherical Surfaces in a Lathe.—Many machine constructions call for spherical surfaces, but in few cases is it

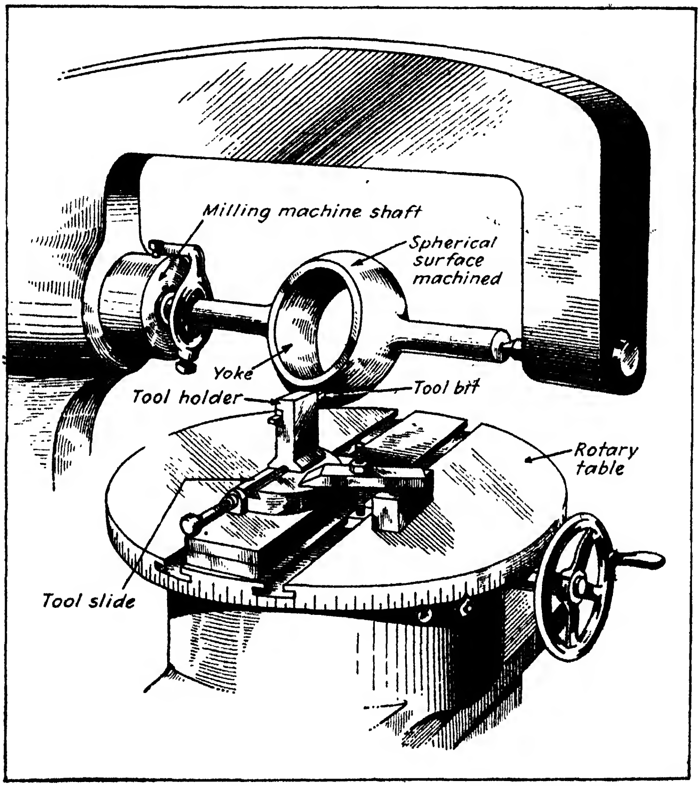


FIG. 20.—Turning a spherical yoke in a milling machine.

necessary to machine complete balls. Spherical surfaces, such as enlarged portions of a shaft to permit universal movement in a suitable bearing, are frequently called for and can be machined on an engine lathe on a production basis with a little preparation. Figure 21 shows how a lathe was rigged up for work of this kind.

The compound rest and a round table were mounted on the cross slide. A 9-in. table will turn spheres up to 4 in. in diameter. With the round table *A* mounted on cross slide *B* the center

line of cross slide *C* is lined up with the center of the ball to be turned. The carriage can be locked in this position or an indicator can be used as at *D* to show when the center lines coincide.

The center of the revolving table must be directly under the center line of the shaft being turned, as at *E*. The indicator *F* can be set to show when the diameter of the ball is correct, or a positive stop can be used as in the other case. With a worm for

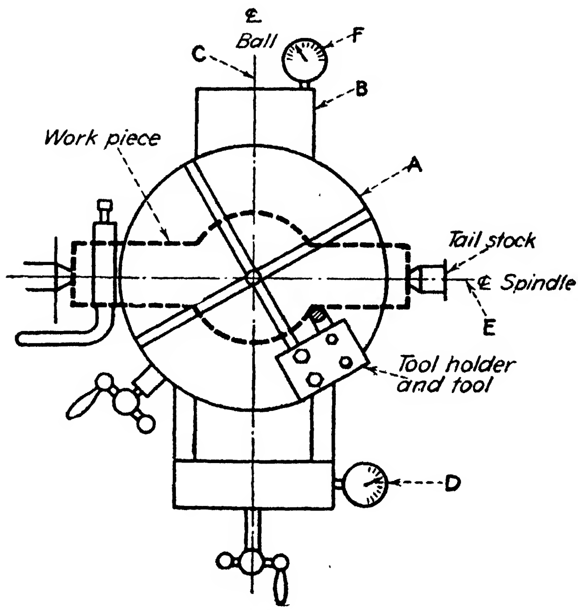


FIG. 21.—Turning a similar job in a lathe.

revolving the table carrying the cutting tool, the work can be turned accurately and easily. A round-nosed tool has been found to be best for work of this kind.

Special Tool Post for Turning Crankshafts.—Turning crankpins or main bearings on a large crankshaft requires a tool post that will permit the tool to be fed into the pins between the crank cheeks without interference. One method of doing this is shown in Fig. 22 where the special tool post has been made with a casting designed for this purpose. Similar results could have been secured by welding pieces of steel plate.

This tool post brings the cutting tool to the center line of the shaft and is narrow enough to go in between the cheeks. The

tool is held firmly in place by a wedge drawn in by the handwheel in front of the tool post. Feeding of the tool is done by the regular cross-feed screw.

It will be noted that the crankshaft is located on offset centers so as to bring two of the crankpins in line. The end plate at the tail center is clamped to the end center bearing of the shaft and has three centers, one for each pair of crankpins. The

FIG. 22 Special tool post for turning the pin between crank cheeks.

flanged end of the crankshaft is bolted to the faceplate where it must be shifted into three positions to correspond with the centers on the tail end. It will also be noted that a sling in the center helps support the weight of the shaft while it is being turned.

Big Roll Job in Railroad Shop.—There are few railroad shops that can boast of possessing a lathe swinging normally 76 in. and taking work between centers over 43 ft. long. Actually the Southern Pacific's lathe illustrated in this article has at times been jacked up on raising blocks for certain crankshaft jobs to an even larger capacity as to swing. This lathe bed has recently been stretched out about 9 ft. in order to make possible the

handling of a series of long, heavy bending rolls for the Oregon Shipbuilding Corporation, near Portland, Ore. The lathe has long been a very useful member of the heavy tool equipment at the Southern Pacific general shops in Sacramento; in fact, it was installed in 1903, a Putnam heavy machine of that period, now over 40 years ago.

FIG. 23.—Turning a 43-ft. 10-in. forged roll

Since the date of installation of this long bed lathe there have been many instances where it has been of first importance in machining long shafts, cranks, etc., for the company's marine equipment—passenger and car ferry boats. Now this machine and certain other shop facilities have been utilized as an aid to shipbuilding, that is, in the preparation of steel rolls for plate bending operations, as noted above. It represents a striking

example of the ability of the company's expansive shop facilities to back the nation's industry in vigorously prosecuting our war program.

The steel rolls referred to are the largest ever turned in the Sacramento shops and were machined for assembly in the largest

FIG. 24.—Squaring the far end on a double-head slotter.

plate-bending rolls ever built. Each bending unit consists of three rolls.

The two lower rolls of each bending unit are 43 ft. 10 in. long, 20 in. in diameter (finished), and weigh 26½ tons. They were forged by the Moore Dry Dock Company of Oakland. The top roll of the unit is 40 ft. 8 in. long and weighs 30½ tons. Its diameter—finished—is 31½ in. Each top roll was cast in two sections by the Columbia Steel Company at their Pittsburg,

Calif., plant. The two sections were welded together at the Pray Machine shop, San Jose.

A striking picture is presented in Fig. 23, showing the big lathe with one of the 43-ft. 10-in. forged rolls in place and approaching finished condition. Note the use of big steady rests to aid in properly supporting the heavy job. The machinist in the foreground is seen checking the diameter of the roll with a large frame micrometer. In connection with the extension of the bed

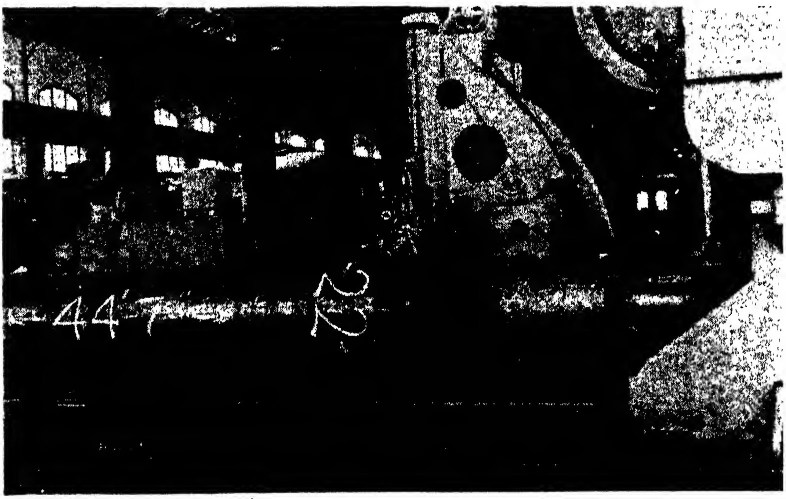


Fig. 25.—Close-up of a slotter tool squaring the end of a shaft.

of this lathe, it may be explained that the headstock end was extended 6 ft., while an addition of 3 ft. was made at the tailstock end. The original motor, a 15-hp. unit on the head—was changed to a 45-hp. driving unit. The four forged steel rolls forming the lower members of the two bending units were made of S.A.E. 1030-1040 steel.

One of the first operations to be performed upon arrival of the rough-forged rolls was to finish the ends to length prior to placing the work in the lathe. Here, again, a machine familiar to this shop, but certainly uncommon enough to the general machine shop, was called into service for squaring the roll journal ends to length. This machine, seen in Figs. 24 and 25, is a double-head slotter used at Sacramento for such typical jobs as machining side frames, slotting pedestal jaws, and similar projects where the

length of the bed and wide spacing of the heads enable long work to be handled readily and economically.

Figure 24 shows the skillful handling of the overhead cranes in the erecting shop and the machine shop, which, working in unison, transferred the heavy roll forging to the bed of the double slotter and afterward removed it into position for mounting in the lathe.

FIG. 26.—Milling a 2 in. wide keyway in a roll.

Figure 25 is a close-up showing the application of the slotter tool to the facing off of the roll end.

"Catheads" on this big work, centered by set screws on the rough roll, enable the work to be run in steady rests while turning down all over in preliminary lathe operations.

Among other features of these shops are the big Morton draw-cut shapers which have been applied to many unique or at least unusual types of jobs. Here in Fig. 26 are illustrated combined operations under two milling cutters with the mills mounted on spindles carried in the shaper rams. Boring and milling are readily performed on this type of machine; indeed, they add much to the flexibility and diversity of the machining processes to which the drawcut tool is adapted. The two milling cutters in the illustration are engaged in milling a keyway at the end of

the roll and a series of narrow slots along the working face of the roll. The keyway being cut is 2 in. wide by $5/8$ in. deep and is for taking the drive on the neck of the roll.

These cast-steel rolls are $31\frac{1}{2}$ in in diameter. They are $30\frac{1}{2}$-ton units. One of the rolls, composed of two sections welded together, is shown in Fig. 27 located on heavy I beams in position for boring the ends to size to receive stub axles which are used to form the journals of these upper rolls

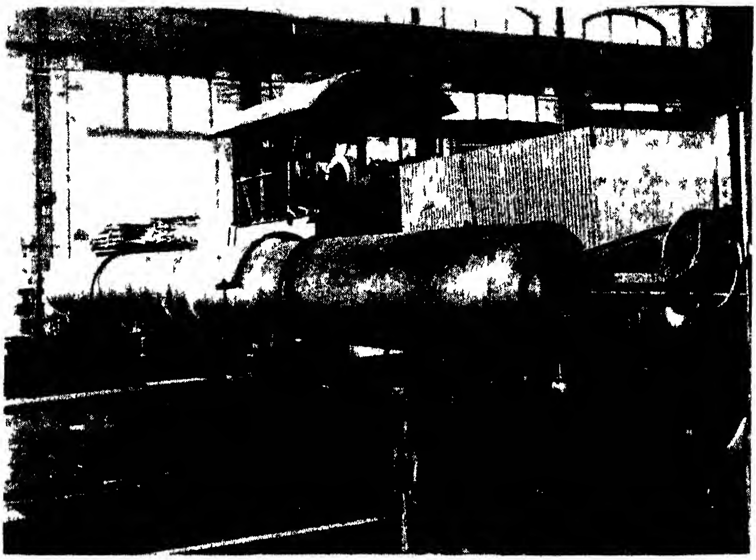


FIG. 27.—Boring the end of a roll

The boring of the roll ends is accomplished, as indicated, with the roll end aligned with the spindle of the horizontal boring machine, and a multiple-tooth boring head is used for sizing the hole. The stub axles used for these big rolls are about $34\frac{1}{2}$ in. long, with the end that fits into the axle end having a diameter of 14 in. and a length of fit of $19\frac{1}{2}$ in. The projecting end or bearing end is 15 in. long by 13 in. in diameter, and a liberal fillet is formed between the two diameters of the axle body.

The body fit of the stub axle is sufficiently large to provide for a snug shrink fit in the end of the roll. The preparation of the roll in making the shrink fit is carried out in the specially built furnace (Fig. 28), where two oil torches are applied for about 3

hr. to the end of the work to expand the bore to a satisfactory size for making the shrink fit for the stub axles

Turret Lathe Work.—The advantage of using a turret to carry more than one tool is shown in Fig. 29. These settings are from work done on the Bullard vertical-turret lathe, or boring mill By turning the illustration so that the work revolves in a horizontal plane, we have the conditions in a

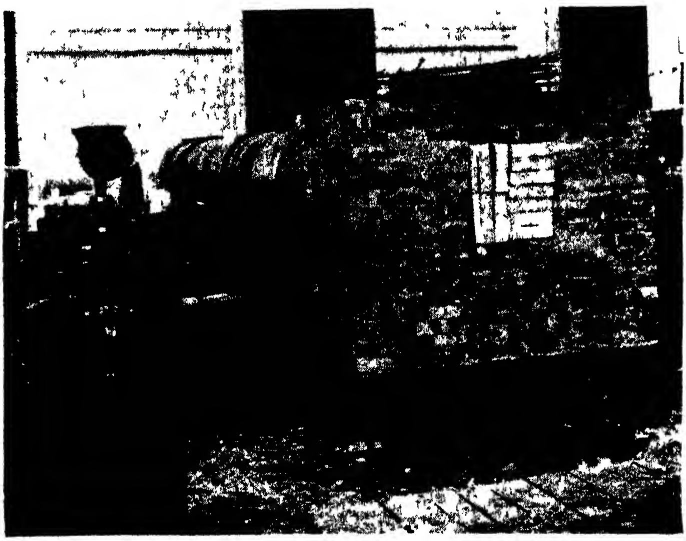


FIG. 28.—Heating the end of a roll for shrinking on a stub axle.

horizontal-turret lathe or in an engine lathe. The work could be done on either of the lathes mentioned, but the engine lathe would require more operations and more tools than can be held at one setting. Advantage of the vertical machine is the ease with which work can be placed on the table and centered as compared with the horizontal machine. Where work is held in a chuck, as in Fig. 30, there is less choice as to which machine to use, although chucking is easier on a horizontal faceplate.

The first job is a sheave pulley held and supported by the arms *A* on the table or faceplate, depending on which type of machine is being considered. Set so as to clear the table as in the first operation, both sides of the face or rim are machined. The upper surface is faced with a tool in the turret and the lower side by a tool in the side head, which corresponds to the carriage

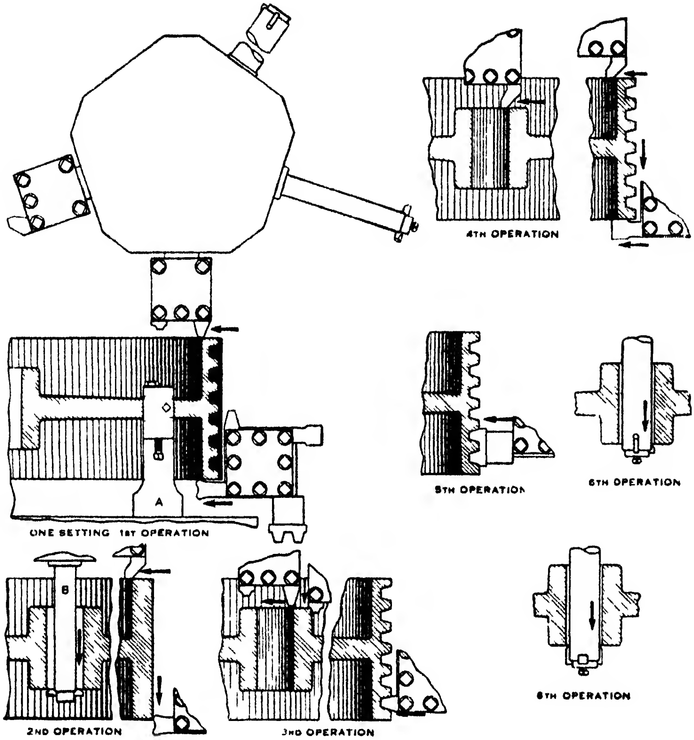


FIG. 29. How several tools can be used to advantage on a vertical boring mill

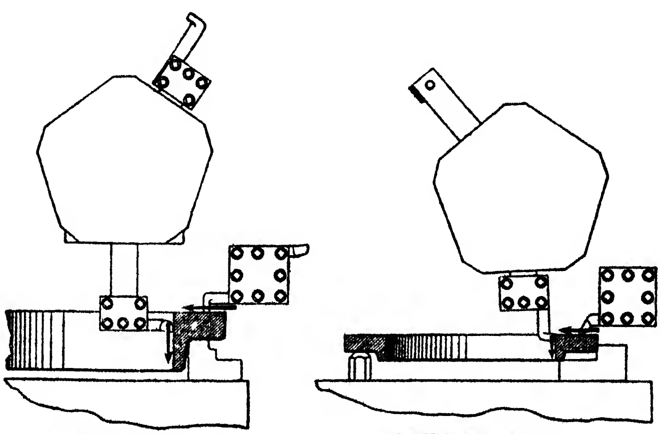


FIG. 30.- Holding work in chuck jaws with supports between them.

of an engine lathe or the cross slide on a turret lathe. Arrows show the direction of the feed in each case.

In the second operation the upper edge is being finished by the second tool in the turret and then the hole is rough-bored by bar *B*. At the same time, the outer diameter is being turned. Operation 3 faces across the hub and also uses the smaller chamfering tool to round the corners of the hub. The other side of the same tool can round off sharp edges of the rim.

At the same time, the rim is being grooved by one tool in the side-head turret tool post. The next operation faces one side of the hub and both sides of the rim, using tools in both the turret and the side head. Operation 5 finishes the grooves

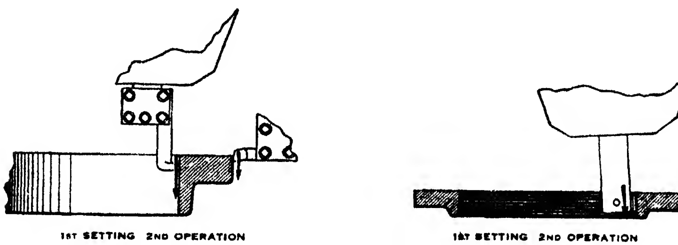


FIG. 31 Machining plain and threaded flanges.

using the double-pointed tool, while the next operation finishes the bore with the other bar in the turret.

Two types of flanges are being machined in Figs. 30 and 31. The first is a plain flange, and the other is threaded for pipe. Operations of the tools are shown by the arrows in each case Both jobs are held by chucks, and the jaws show how they are held. The thread can be cut in one or two passes.

In Fig. 32 a method of machining gear blanks on this type of machine is shown in detail. By following the operation numbers and noting the direction of the arrows, it will be easy to see just how the sequence of operations is laid out for work of this kind.

Five operations are performed at the first setting. The first rough-faces the upper side of the gear blank and recesses the hub. The second rough-bores the hub and finish-faces the upper side of the gear. The third operation finish-bores the hub and roughs the outside down to the chuck jaws.

In the fourth operation the hole is reamed and the outside finished. In the fifth, the face is finished and the recessed hub also brought to finish dimensions.

The first operation of the second setting rough-faces the other side of the gear blank, using two tools on account of the difference in the height of the faces. At the same time the outside is being roughed down to meet the first cut from the other side, in the

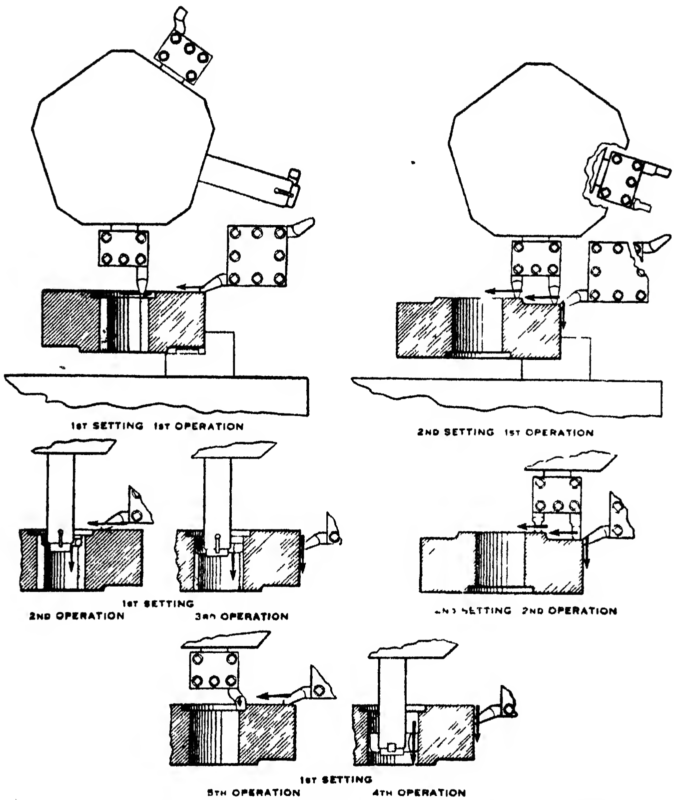


FIG 32 Sequence of operations in machining a gear blank

first setting. The second operation of this setting finishes the gear blank on both the top and outside diameter, as indicated by the arrows.

Tapping in a Boring Mill.—In most cases the threading of a ring as large as the port-light frame shown in Fig. 33 would be done in a lathe by chasing in the regular way. The ring is 16 in. inside diameter and has an 8 thread for a depth of about 1 in. In this case the number required justified the making of a large

collapsible tap for the work which was done on a Bullard 48-in. boring mill.

The tapping head combines a series of chaser blades operated by a cam member which is moved by the hand lever to expand the chasers into working position and to retract them to neutral place upon completion of threading the interior of the bronze castings. The head carries also a series of cutters for finishing the interior of the bore and facing the upper edge of the work.

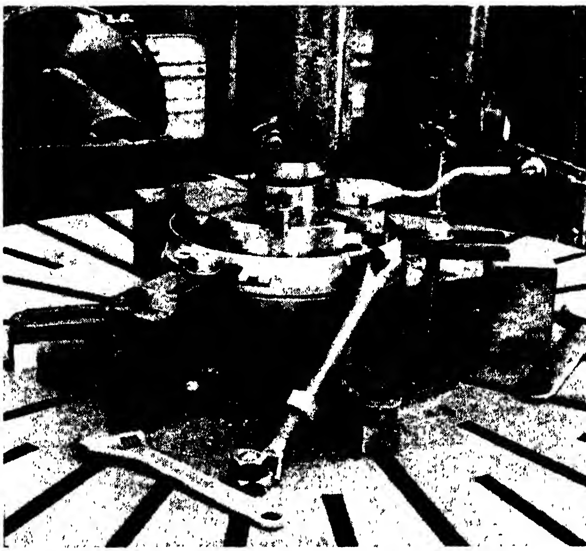


FIG. 33.—Tapping a 16-in. ring in a boring mill.

While the boring cutters are at work inside the piece, the threading chasers are retracted and in the clear when the head is fed down in the boring operation. When the head is raised, the tapping chasers are expanded into working position by movement of the hand lever, and the head run down one pass to form the thread.

The work is held in a special fixture on the table of the boring mill but further assurance against its turning against the action of the tapping head is presented by the strut seen placed between a lug on the work and a stop on the table of the mill.

Heavy Boring in the Turret Lathe.—Boring of alloy-steel spindle forgings for modern lathes is a real boring job. The boring bar and method used by the Warner and Swasey Co. are

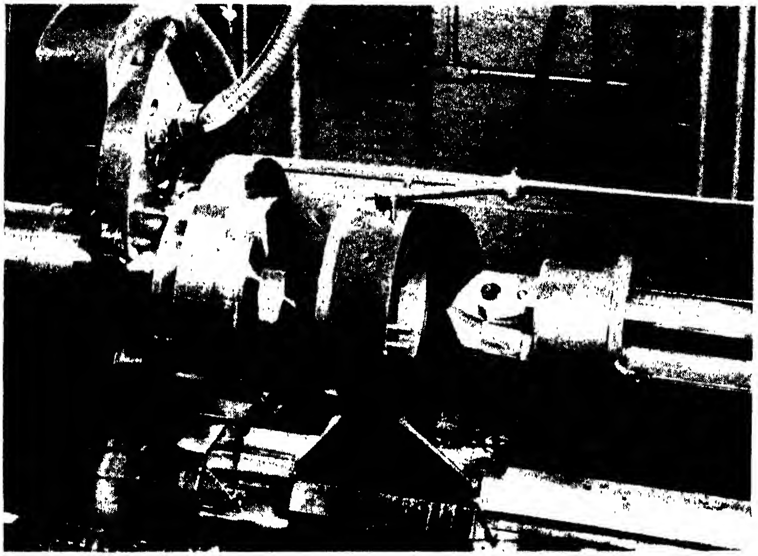


FIG. 34.—Guiding a boring bar for heavy work in a turret lathe.

shown in Figs. 34 and 35. The first shows the spindle supported in a substantial roller steady rest, the support for the boring bar, the collar inside the work support, and the boring bar used.

The bushing on the bar fits inside the stationary support on lathe bed. By the use of different bushings, boring bars of different diameters can be used in the same stationary support. The plastic handles on the bushing are a convenience in handling it in and out of the support.

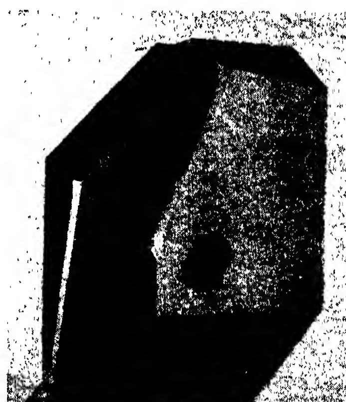


FIG. 35.—How the boring cutter is made.

The boring cutter itself is shown in Fig. 35. As will be seen, each lip is ground down about half its thickness to secure radial cutting edges. This brings the center angle so that it cuts easily. The serrations on the edge break the chips and make it easy for them to be washed out of the hole

Machining Rotary Joints on the Turret Lathe.—Rotary hose joints, made by Chiksan Tool Co. in Southern California, are in large sizes as well as small. In all cases they are a turret lathe product, various types of faceplate fixtures being used for holding the work for machining operations, as shown typically in Fig. 36.

The tools used are built up chiefly of heavy holders with high-speed steel cutters inserted in slots in the tool holders, the slots cut at an angle to give the tools the freest cutting position against the work. Each tool bit is secured by two or more hollow-head

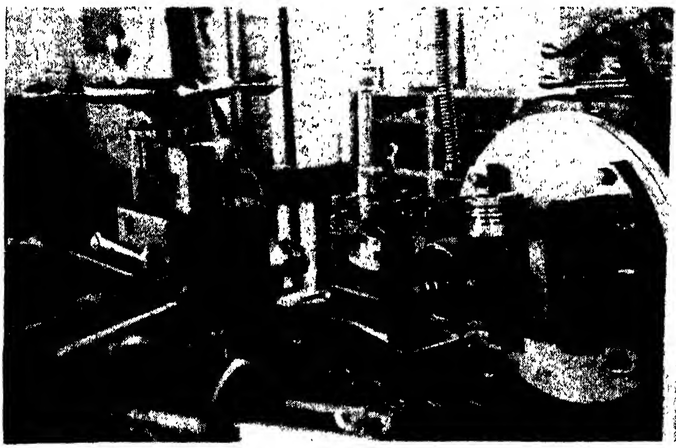


Fig. 36.—Machining rotary pipe-line joints in a turret lathe.

setscrews, and there are no projections from the bodies of the tools except the ends of the tools themselves.

The pipe joints are located and secured in fixtures on the faceplate for machining of the ends and all fitting surfaces, including the grooves for ball races which enable the joints to swivel so freely on each other when the units are assembled for use.

The method of holding the work in swiveling faceplate fixtures is clearly shown. The machines are of various sizes by Warner and Swasey, but all are adapted to rugged operations. The grooving tool shown in the turret is a forming tool with multiple teeth smaller than the interior of the fitting in which it is to cut the groove; hence it has ample clearance for the outside diameter when run into place. As one tooth or cutting edge becomes worn or dulled, the tool can be adjusted around on its stud to

bring another tooth into working position. The grooving tool is mounted on the regular vertical slide tool holder.

The tools shown in Fig. 37, like most of the others employed on this job, are composed of very heavy steel bodies in which the cutting blades and bits are inserted as spirally located members to provide a smooth shearing cut. All bits are independently located and adjustable as required. The roughers remove the bulk of the material leaving a suitable amount for finishing cuts.

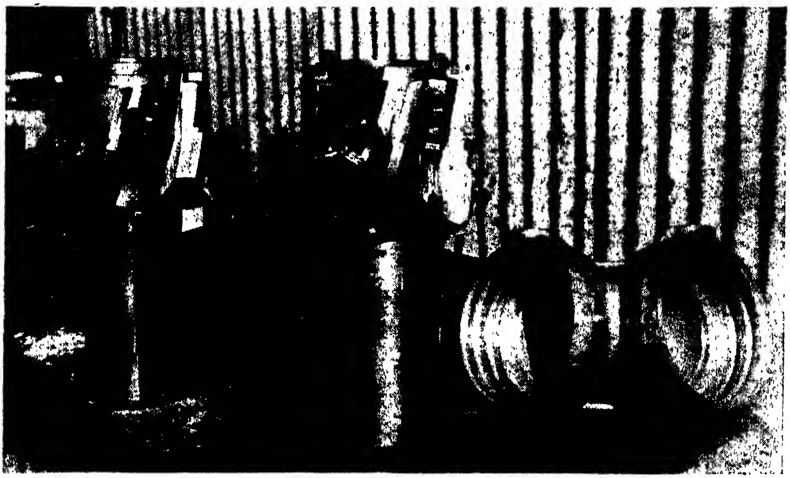


Fig. 37.—Tools used in operation shown in Fig. 36.

One of the big angle joints is shown on the bench alongside of the turret tools. These tools are for the internal joint fit. They are adapted for finishing operations in the inner end of the joint, for facing and turning the end, and for finishing the ring seats and similar parts.

Corresponding tools for external cuts are also made, with arms widely spread to form outside turning cuts and the like. The effect is similar to a hollow mill except that they are two-cutter types only and of very large proportions.

Drill Speeder on Turret Lathe.—The turret lathe attachment shown in Fig. 38 is used by a gun-sight factory for speeding drills carried in the turret. The drive as shown has a bracket to fit the turret and is supplied with a driving gear. The gear is actuated by a short spindle at the rear of the work spindle. This short spindle takes power from the self-contained counter-

shaft shown at the back of the head. The connection is by silent chain and sprockets. The effect is to speed up the short auxiliary spindle which imparts a high rate of speed to the drill speeder gear when the latter is swung around by the turret into alignment with the auxiliary spindle. This spindle has a telescopic construction The projecting member, which contacts

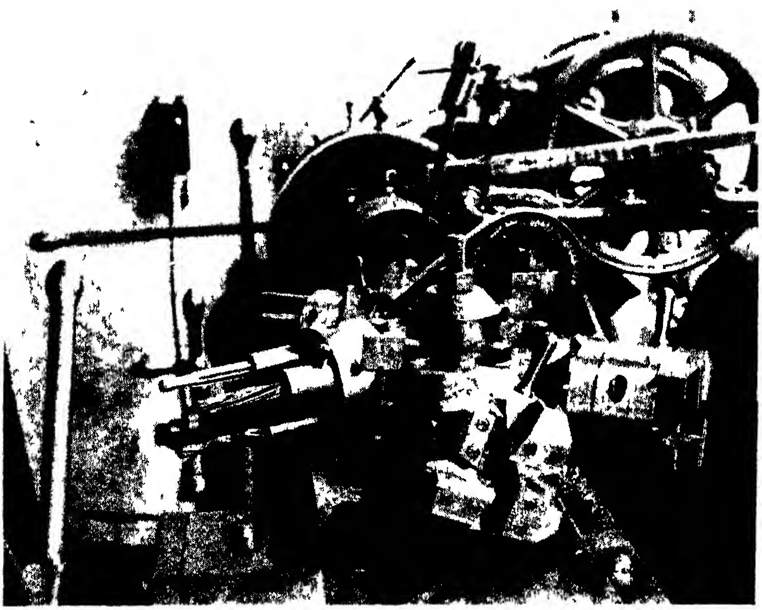


FIG. 38 This is how a gun-sight factory speeded the drilling operation on a turret lathe

with a clutch on the gear drive, telescopes inwardly against spring pressure so that, as the turret feeds forward, the drive member can recede but still retain its driving contact with the drill speeder.

The device gives a speed of 450 r.p.m. to the drill and, as the work spindle of the turret lathe is driven at 130 r.p.m. on the job shown in the chuck, the actual rate of drilling is 580 r.p.m. The drill used prior to reaming is 0.296 in. in diameter.

This small drilled hole put through at the higher speed is used ahead of a series of reaming operations performed with other tools in the turret where the slower regular rate of speed is required.

Planetary Hollow Milling.—A good example of planetary milling in a modern machine is shown in Fig. 39. This is really a turning operation, using a special tool. The figure shows the construction of the cutter very clearly and the way in which the cutters are set for milling an aluminum forging, which is the shank of a propeller. This differs from the original method of hollow milling in that the inner diameter of the cutter is considerable larger than the diameter of the part to be milled.

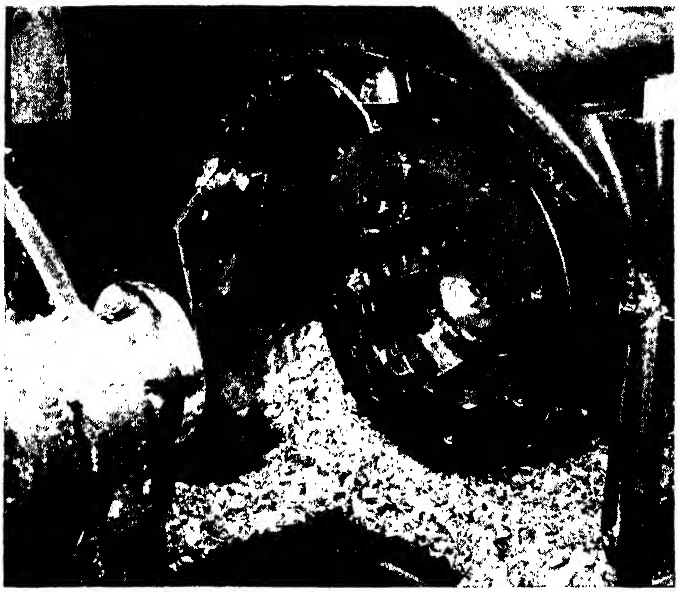


FIG. 39.—Milling head and work on a Hall planetary milling machine.

Instead of simply being forced over the work with the hollow mill central with the axis of the work, this cutter both revolves and travels around the stationary propeller shank. Each of the cutting blades contacts the work as the cutter head revolves once around the work. This is called "planetary" milling because the cutter travels around the work just as the planets travel around the sun. The work remains stationary.

A smaller cutter, seen inside the big one, mills the interior of the hub at the same time the outer surface is being machined.

With the Hall planetary milling machine, which was the first standard machine of this type, the main spindle carries the

cutter either for plain, contour milling or for threading. The head has two eccentric sleeves by which the cutter can be offset any desired amount. The work is fixed on the lathe carriage, which is an advantage where the work is heavy or of awkward shape. The work can be fed either longitudinally or radially as the operations demand.

Cutters of the Hall machine have internal teeth as seen in Fig. 39 and resemble those of an internal or hollow milling

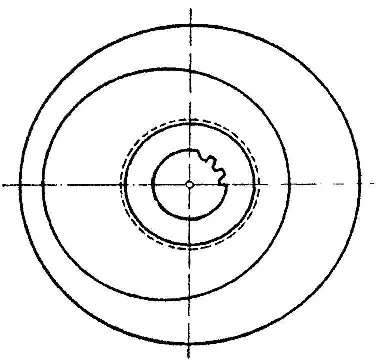


Fig. 40.—Cutter in center.

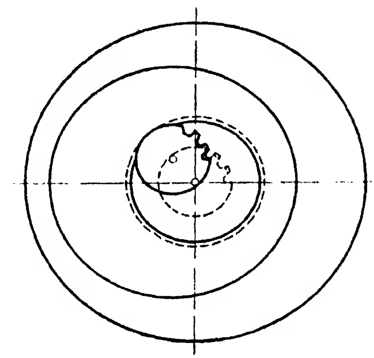


Fig. 41.—Cutter moved out of center—dotted line shows center position.

cutter. However, there is this distinct difference. With the hollow mill the diameter of the work is determined by the internal diameter of the cutter as all teeth cut at the same time. With the planetary machine the cutter is larger than the work, only one tooth contacting the work at a time.

Where the Hall type of machine is used in internal work, the cutter must, of course, be smaller than the work. These machines are used for threading as well as for milling, on both internal and external work.

Distinction should be made between the planetary and rotary types of milling machines. Although the rotary machines can do similar work, they operate on an entirely different principle. They are simply milling machines using regular types of milling cutters operating on the outside or inside of round work which is revolved past the cutter or in which the cutter is on a spindle that moves past the work. Machines of this type are made by

both Newton and Cross, some operations on each being shown herewith.

The diagrams show how the cutters of the Plan-O-Mill work in planetary milling, which is really a turning or boring operation. The cutter is carried on a spindle that runs in an eccentric quill or sleeve. In Fig. 40 the quill is turned so that the spindle and its cutter are in the center. In Fig. 41 the central position of the cutter is shown by the dotted line. The solid line shows that the quill has turned so that the cutter is forced into the work.

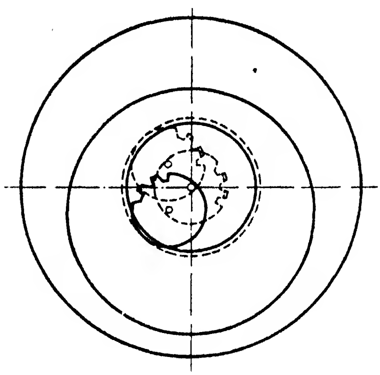


FIG. 42.—Milling cutter is carried around the work.

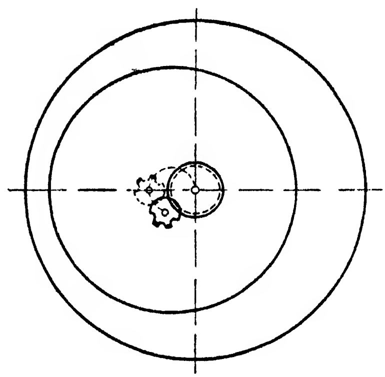


FIG. 43.—Here the milling cutter is working on the outside of the piece.

As shown in Fig. 42, the inner quill has engaged the outer quill which begins rotating and carries the milling cutter around the work. When the outer quill makes one revolution, the work is done. This shows the cutter as it moves around inside the work in this case. In Fig. 43 the cutter is outside the work, but the action is the same.

This can be used in plain milling, in contour milling with formed cutters, or with thread milling hobs for cutting threads either inside or outside of the work.

Several advantages are claimed for this type of milling. The work remains stationary, which helps greatly when the work is large and cumbersome to fasten and revolve. This makes it possible to use a smaller and lighter milling machine and work can be handled that would be very difficult if the work revolved. For many classes of work, it is also much more convenient than a lathe, largely because it is frequently much easier to have the

FIG. 43a.—A Cross Mil-lathe or rotary milling machine.

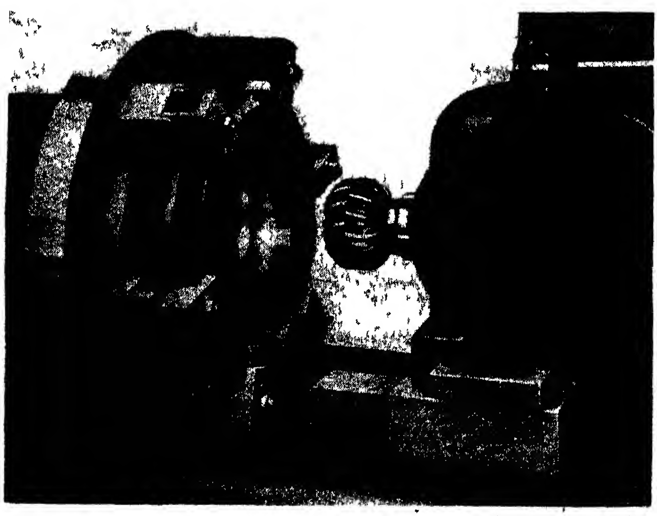


FIG. 43b.—A Cross rotating milling machine, or Mil-lathe, at work.

work remain stationary and move the tools around it, as in this case.

Cross Rotating Milling Machine.—The Cross rotating miller, or Mil-lathe as it is called, differs from the Hall design in having the work revolve and the cutter mounted in a head with a cross-sliding movement as seen in Fig. 43*a*. It can readily be seen that the interlocking form cutter shown will mill a circular slot inside the work revolved by the chuck. A close-up of this is seen in Fig. 43*b*.

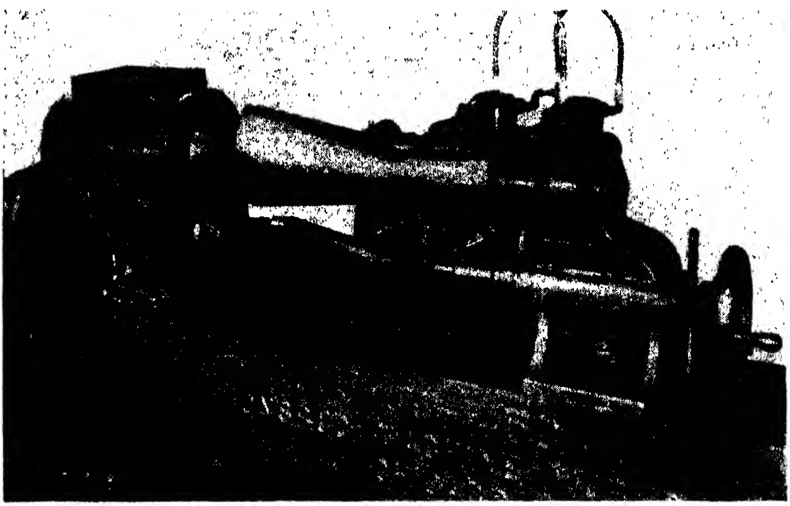


FIG. 44.—Onsrud forming lathe shaping a gunstock.

It is evident that similar milling can be done on the outside of work, properly held and within the capacity of the machine. Figure 43*b* also shows details of the simple type of jaws or clamps used to hold the work. The bases for these clamps are welded to the faceplate or chuck body and support the other ends of the clamps; they also afford an anchor for the fixed end of the studs used for clamping.

Reproducing Irregular Forms.—Reproducing irregular shapes by using a master former seems to have originated in the old Blanchard wood-turning lathe which was designed for making gunstocks by machine instead of by hand. This same principle is used in producing shoe lasts, chair legs, and other articles of wood.

Later developments use rotating cutters instead of knives as was originally the case. A late development along this line is seen in Fig. 44 where a modern machine is turning gunstocks for the present conflict. The model or master form is shown at the top and is twice the size of the gunstock being turned. This reduces any errors that might exist in the pattern or model.

As the model and the stock to be turned are geared together, they both turn at the same rate. As they turn, the two end

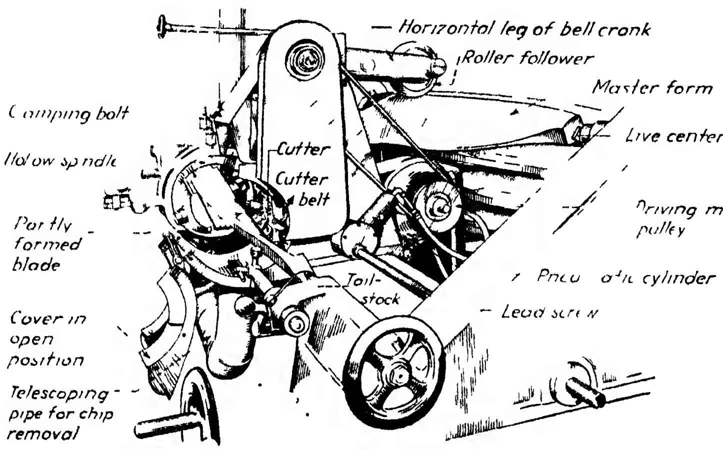


FIG. 45 —Forming airplane propeller blades with rotary cutter

cutters shown remove the surplus wood from the blank and leave the gunstock ready for finishing. The cutter head moves in and out and keeps the follower roller against the upper form at all times. This form is usually of cast iron or other suitable metal.

The same principle is used in a machine for shaping wooden propellers and is shown in outline in Fig. 45. Both the blade and the former rotate slowly, but the cutter runs at high speed. As the follower roll is at 90 deg. from the blade being cut, the former must be set in the same way. A lead screw feeds the milling head along the bed of the machine.

Somewhat similar machines are used in shaping metal propeller blades for airplanes. In some, an edge-cutting milling cutter is used and, instead of revolving, the cutter goes back and forth across one side of the blade at once.

Turning in the Horizontal Boring Machine.—Although it is more common to find the engine lathe used as a boring machine, there are occasions when a boring machine is available while a lathe of large enough swing is not. A few examples of this will show how large work can be turned in the boring machine in a satisfactory manner.

In Fig. 46 the base column of a drilling machine is being turned in a Lucas boring machine, using two turning tools: one at the

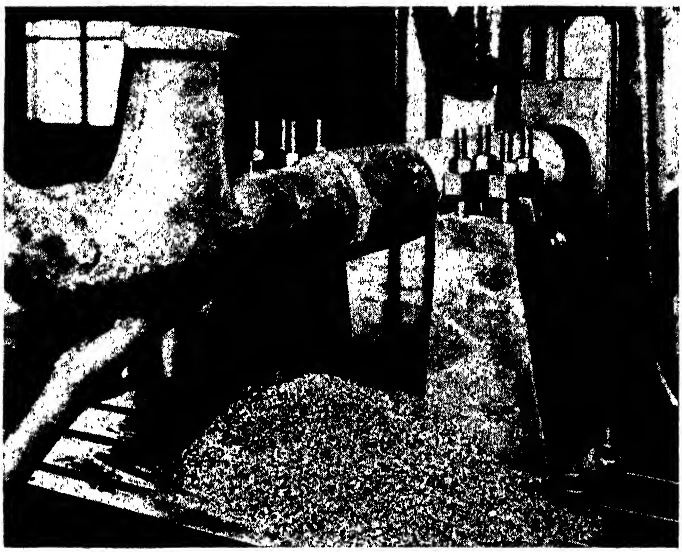


Fig. 46.—Turning drill press column in a boring machine.

front and the other at the rear. As the head of this column is so large that it would take a larger lathe than was available, the boring machine was used. The column is driven by the spindle of the machine, and a tail center in the outboard support carries the round end.

The tool posts are plain hollow columns cast for the purpose and hold the tools firmly by the two straps shown. With one tool to rough the column and the other to finish it, the work can be done in one pass. The pile of chips shows that real cuts were taken in doing this turning job.

Another and much larger turning job is shown in Fig. 47. Here again, as there was no lathe large enough to swing the piece of work, the boring machine was called into play. The

drum is mounted on a mandrel and is driven by the piece projecting from the star-feed facing tool. This contacts the piece on the drum and drives the drum. The tool post resembles the other but is of a different construction.

A third job of turning is shown in Fig. 48. Here the work is the frame of a riveting machine which is held on the table of the machine as shown. It is held by jacks and clamps as can be seen.

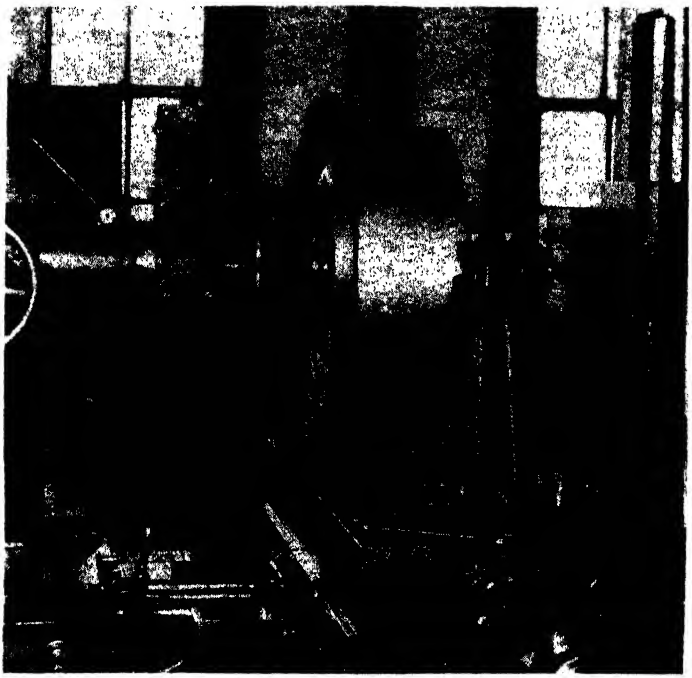


FIG. 47.—Turning a large drum in a boring machine, using a dead center in the outboard support.

The turning is done by a hollow milling cutter which is shown on the end of the spindle. It is a hollow sleeve with cutters in the front end which turn the trunnion as seen at the other end. The different diameters shown at the other end are produced by having several cutters in the hollow milling head. The feed can be secured either from the spindle or by moving the table and the work toward the head. The former seems the more feasible in this case.

Uses of Sweep Tools.—Sweep tools are very useful in many operations such as turning or facing the ends of work that is too

large or too awkward in shape to be revolved against a stationary tool, as is usual for such work. Although the piece of work shown

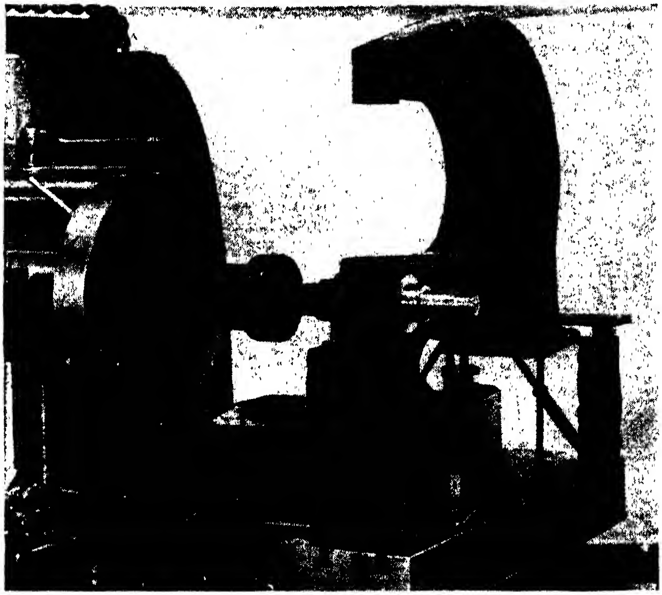


FIG. 48.—Turning the trunnions of a riveting machine frame with a hollow mill.

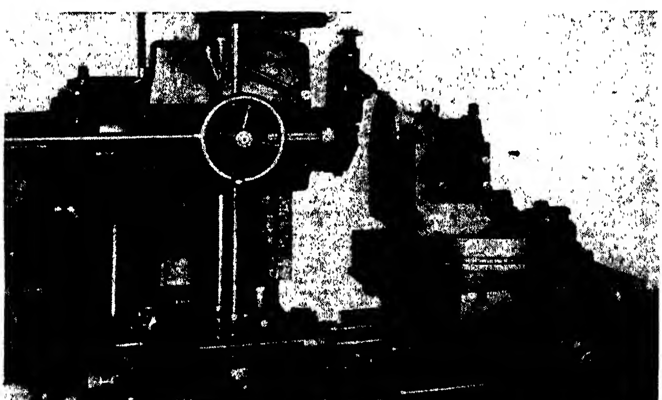


FIG. 49.—Using a sweep tool on a Lucas boring machine to turn the outside of a flange.

in Fig. 49 could have been held in a similar fixture on a lathe or a vertical boring mill, this method was considered the best in this

case. It will be noted that the pin that gives the cross feed to the tool is swung up out of the way as the tool is shown turning

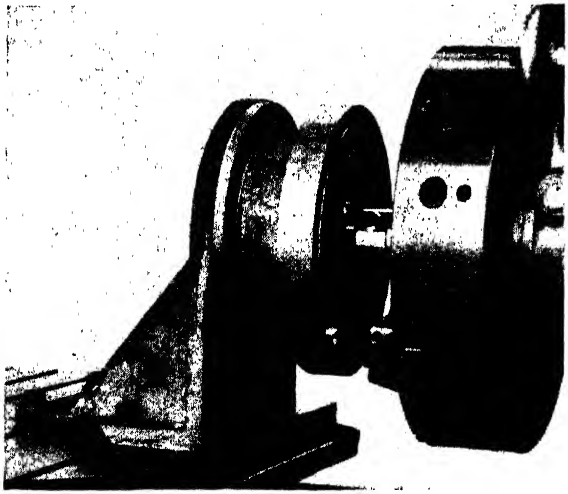


FIG. 50.—Giddings and Lewis toolhead used in boring.

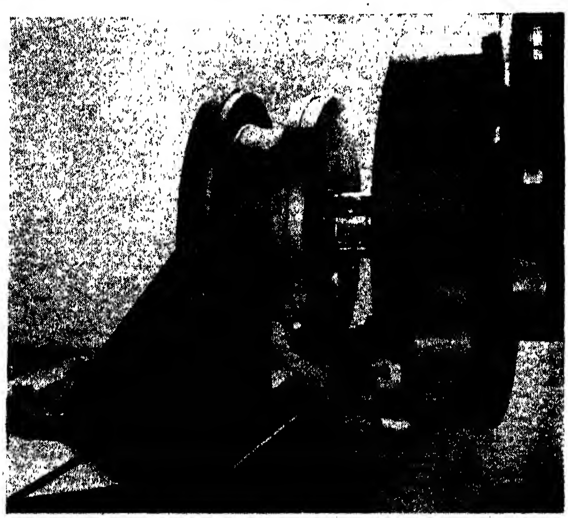


FIG. 51.—Turning and boring at the same time.

the flange instead of facing it. For the facing operation, the pin is turned down so that it feeds the tool across the face of the flange.

The Giddings & Lewis Co. have developed a type of sweep tool with a constant feed for use with their horizontal boring machines. This is shown in Figs. 50 to 52.

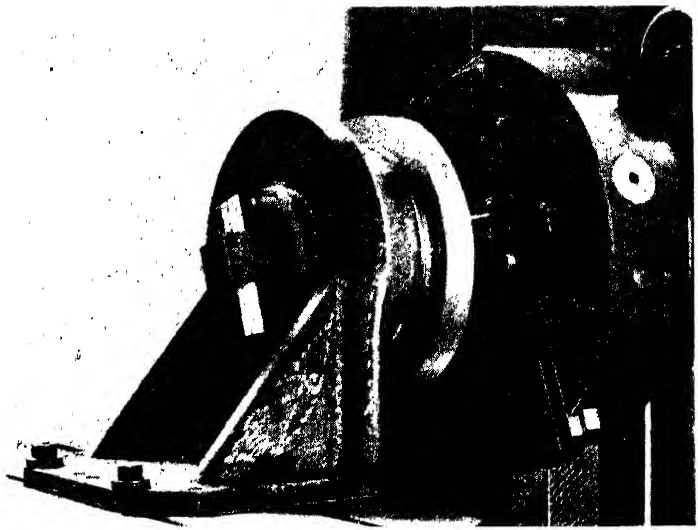


Fig. 52.—Back facing the same piece with a tool driven by the toolhead.

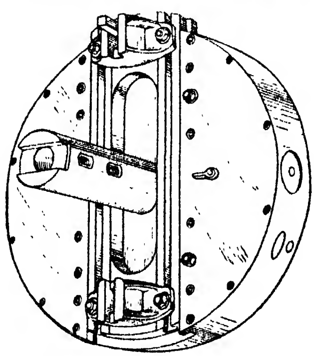


Fig. 52*a*.—This head has a positive feed.

Toolhead without the Star Feed.—Instead of the usual star feed commonly used on facing and boring heads these have a continuous feed instead of the intermittent one generally used. This is shown on three types of work in Figs. 50 to 52. In the first the micrometer-adjusted tool in the center is boring and facing a flange of the angle casting shown bolted to the

table. In Fig. 51 the outer diameter of the flange is being turned by the special O.K. toolholder shown. The surface next to the base of the casting has already been turned and faced.

The same outer tool is being used in both Figs. 50 and Fig. 51. In facing the flange, it is simply moved into the holder to reduce overhang. In the third operation (Fig. 52) the rear face of the

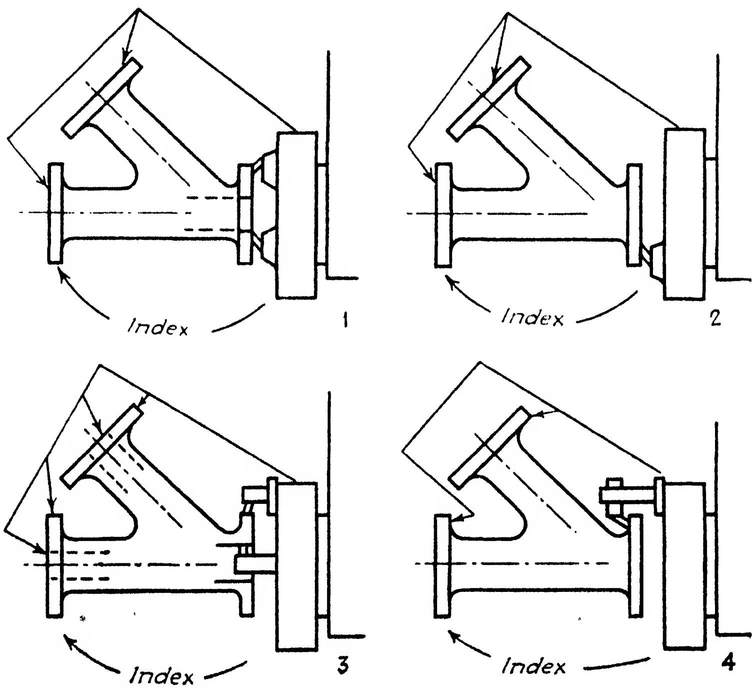


FIG. 52b.—These four outlines show different operations on the Y casting. The work is indexed to permit the cutting tool to reach all the flanges.

casting is being backfaced by a special toolholder designed for work of this kind. Here the cross, or facing, movement of the tool head furnished the feed for the tool across the rear face of the work. This view also shows the tool slide which extends across the face of the tool head. This makes a very substantial design and gives an attachment that can be used in machining many different surfaces.

The construction of this positive feed toolhead is outlined in Fig. 52a which indicates the absence of the star feed. Four

tool settings possible with this toolhead are seen in Fig. 52*b*. These outlines show how all the operations on any of the three flanges can be performed. Similar operations can be done on any of the flanges when it is indexed, or located in the correct position. These are not manufacturing operations, but they

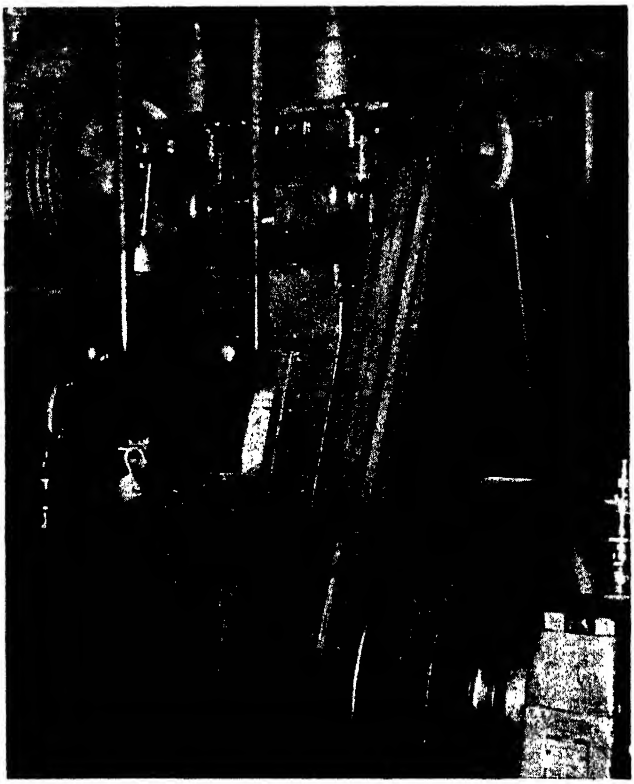


Fig. 53.—Using two Ford transmissions for speed changers.

make it possible for the job or contract shop to handle work that might otherwise go to other shops.

Automobile Gear Shifts for Machine Tool Work.—Automobile transmissions have been used in many ways to secure the desired speeds changes and controls on machine tools of various kinds. In Fig. 53 two transmissions from Ford cars were used by G. E. Beard, a Navy machinist's mate, to give him the speeds he needed in both directions. Mounting these on substantial

supports over the head of the engine lathe, he used one for each direction of rotation. Multiple V belts run on sheaves on the transmission shafts, but the inside of the belts runs directly on the regular flat belt cone of the lathe.

Special shift levers were put on the transmissions so as to bring the handles down to a convenient position. When it is desirable to turn the lathe by hand, the shift levers are put into neutral position. This arrangement gives 17 speeds in either direction, the speeds ranging from 1 to 185 r.p.m.

Chucks for Turning Oval Shapes.—Chucks for turning ovals, sometimes called "wabble" chucks, are not new. Figure 54 was made from a photograph taken 50 years ago in a small Philadelphia shop. Such chucks are not used often, but occasional inquiry indicates that some still want them. The chuck shown was made to turn punches and bore dies for making the tops and bottoms of oval dinner pails, which was the accepted shape at the time. The cover contained a space for coffee which was heated by setting the cover on any warm object in the shop and, unless the cork was loosened, it sometimes blew out with a noise like a firecracker.

Just in case anyone wants to build one, the construction can be easily explained. The slide *A* screws on the spindle nose and is held in guides on the back of faceplate *B*. The back of the faceplate also carried another slide *C*, at right angles to *A*. This slide has a large circular opening in the center.

The other part of the chuck consists of the base *D* which bolts against the face of the headstock so that the spindle nose comes through the opening shown. The sliding member *E* has a projecting ring *G* which fits inside the opening in *C* and controls the movement of the faceplate *B*. The position of slide *E* is regulated by the screw *H*.

With the ring *G* in the center, concentric with the lathe spindle, work bolted to the faceplate will be turned or bored round. Moving ring *G* off center causes slide *C* to move the faceplate along slide *A* twice during each revolution. This combined movement causes the work on the faceplate to move so that a single-point tool will generate an oval. The amount of oval, or difference between the minor and major diameters, depends on the distance the ring *G* is moved.

Oval boring and turning can also be produced by a cam-controlled cross-slide movement. By either method it is necessary to be sure that the cutting edge of the tool has clearance at all points of the revolution, and is set at the center of the spindle. In practice these oval chucks are quite satisfactory.

This is one of many adaptations of the engine lathe to special uses.

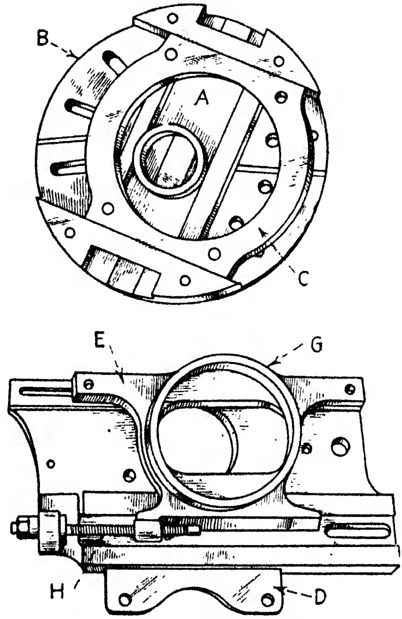


FIG. 54.—An old but efficient chuck for turning or boring oval shapes.

Cutting Clutch Jaws in a Lathe.—Cutting three-jaw clutch faces is usually a milling machine job. But when the Pacific Gear Works Division of the Western Gear Works had a lot of clutches to make and their milling machines were already loaded with work, one of their good mechanics turned to the old standby—the engine lathe. With a simple fixture to hold the work on the lathe carriage and a clever tool (Fig. 55) made on the order of a backing-off attachment, the job was done much more rapidly than on previous milling jobs.

Details of the tool are seen in the figure and can be studied to advantage, as similar methods may find application in other places. The tool bit is mounted in front of a cylindrical holder contained in the casing which is bolted to the face of the round block. This block is prevented from turning by the rod, marked brake bar which bears against the front of the lathe bed.

The toolholder has a three-lobed cam face which matches the stationary cam on the round block. The toolholder also slides on the splined end of the bar that drives it. The spring keeps the two cam faces in contact at all times. As the cutter is driven by the shank, the cam on the toolholder rides on the stationary cam and forces the tool forward. At each third of a

revolution the toolholder drops back when the high spots pass each other and begins moving forward again for the next cut.

Figure 56 shows the clutch before and after cutting. The three radial slots were milled on a Whiton automatic gear cutter

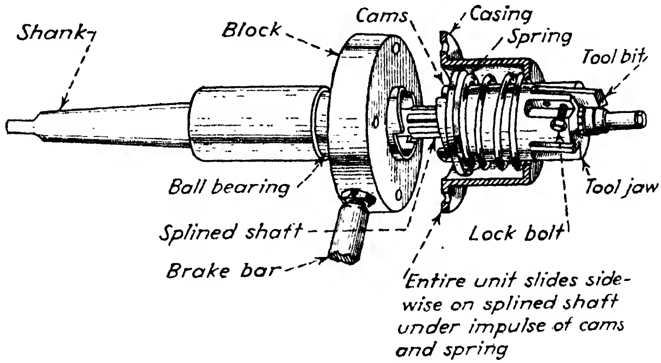


FIG. 55.—Tool and fixture for cutting clutch jaws in a lathe.

to give clearance for the tool and allow time for the retraction of the tool at the end of each cut.

The other end of the tool bar is supported inside the clutch itself to prevent the springing of the tool in the cut. The slotted blank must be properly located so that the cam movement retracts the cutting bit at the right time.

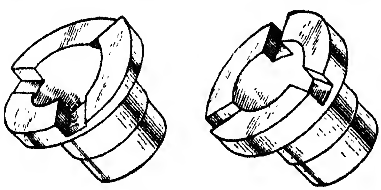


FIG. 56.—The clutch with clearance slots and completed.

The feed is secured by moving the work toward the cutter. This is done by the carriage feed, or by hand or power. It should be carefully watched, however, to prevent feeding to too great a depth.

Attachments.—Attachments that make it possible to increase the kinds of work that can be done on a standard machine are never satisfactory in a production shop. No milling attachment for an engine lathe takes the place of a standard milling machine. But there are many small shops, or even small departments of large shops, where attachments have a legitimate place.

Milling attachments on an engine lathe will enable the odd job to be done which would otherwise have to be refused. Turret

attachments for the cross slide or tailstock of the lathe will often save time because different tools can be brought into position without loss of time. Stops on the lathe bed to control shoulder work or depth of bored holes save time and secure duplication in machining small lots.

Making Turret Lathe Tools in the Small Shop.—Small-shop men who are not familiar with turret lathe work may be called on to make tools for these machines. A few suggestions as to how taps and boring bars can be made in shops with only a few machine tools may be helpful to some.

Figures 57 and 58 show two forms of taps that can be easily made in any small shop. Figure 57 is made from flat bar steel

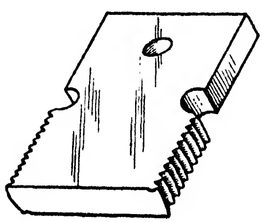


Fig. 57.—The top is made of flat steel stock.

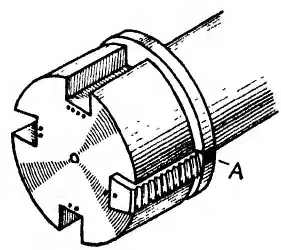


Fig. 58.—An easily made adjustable top for turret work.

and works very well in brass. Made of stock ½ in. thick, this will tap holes of 2 in. in diameter without difficulty and up to 3 in. or more when made of ¾-in. bar. They require very little backing-off. They are held in the slotted end of a bar in a turret lathe, or elsewhere, by a pin through the back end, as shown. The cutter is of course centered in the bar and turned and threaded in the usual manner as though it were a solid round bar.

An adjustable tap, also for turret lathe work, is shown in Fig. 58. The body is of low carbon steel, with a relief groove turned at A. This is clearance for the shaper or planer tool used in cutting the slots, which are beveled, or half-dovetailed as shown. The chasers are easily made and are threaded as though they were solid. As the outer diameter wears, the chasers are set out by putting liners of paper or very thin metal under them. The slots are prick-punched from *one* to *four* and the chasers marked in the same way.

Boring bars, such as shown in Fig. 59, can be easily made in any shop having an engine lathe. The bar is first turned and

then slotted by drilling in the lathe. Lines are scribed on opposite sides of the bar with the point of a lathe tool. Center holes for the drilling are then prick-punched at the proper distance apart. With a drill in the lathe spindle and the bar centered by the punch marks on the opposite side against the tailstock center, the holes are drilled through the bar, reversing after the hole is halfway through.

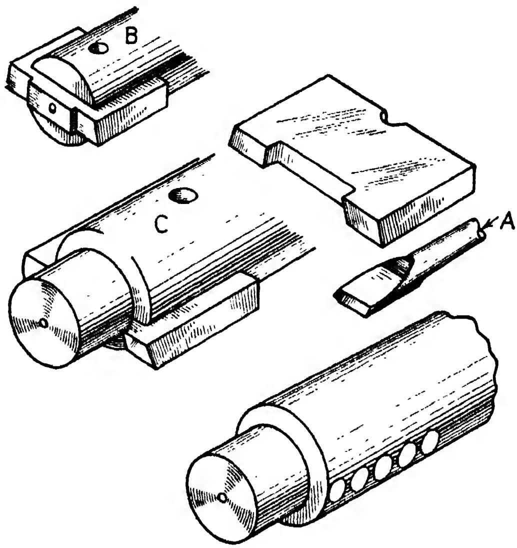


FIG. 59.—Making boring tools in the small shop.

The thin walls between the holes are then cut out with a chisel. A cape chisel can be used, but a chisel with a flat side and only one cutting angle, as at *A*, is better for this work.

Another method is to drill the holes far enough apart to leave a wall of 1/8 in. or more between them. Then plug the holes that have been drilled with soft steel rods and drill through the walls. The plugs in the holes will support the drill on each side. This leaves less metal to be chipped out; in fact, it can be filed without chipping in some cases.

In some cases the cutter is put in the end of the bar as at *B*. In others it is behind a pilot as in *C*. In *B* the cutter is both centered and held by the pin through the bar. In *C* the cutter is centered by projecting each side of the pilot and held by a slightly tapering pin at the back.

CHAPTER VI

MILLING PRACTICE

Changes due to the use of improved cutting materials and the need of greater production to meet the war needs have been particularly notable in milling practice. Although the use of fewer teeth and heavier chips has been developing for a number of years, the change has been most noticeable since 1940. A heavy chip gives greater cutter life but of course requires rigidity in the machine, positive feeds, and plenty of power at the cutter spindle.

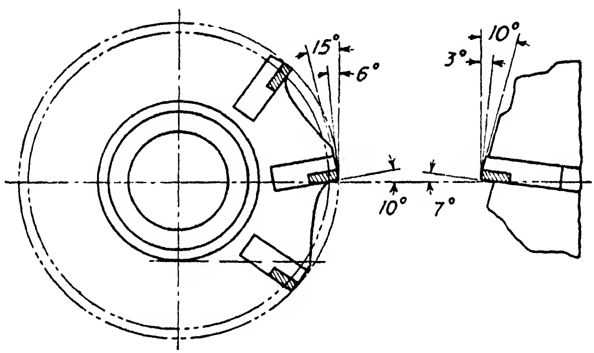


FIG. 1.—Milling cutter with negative rake to protect the cutting edge.

Some advocate one tooth per inch of diameter plus 2, usually to the nearest even number of teeth, while in some cases only half of this number is used, especially in aluminum and other softer metals. Fly cutters with either one or two teeth are also used on aluminum and magnesium. In one notable instance for a heavy cut in aluminum, the cutter is made of four sections, each with one helical tooth. The sections are then spaced so as to form an almost continuous helix for the width of the cutter. It runs at 5,250 surface feet per minute in a cut 3½ in. wide, 3 in. deep, and 96 in. long and removes 200 cu. in. of metal per minute. The chip in this case was about 0.004 in. per revolution

or per tooth. On smaller depths of cut the chip thickness runs up to 0.010 and even 0.020 in. per tooth.

As the feed depends on the thickness of the chip and the number of chips taken per minute, the rule becomes

Chip thickness × number of teeth × r.p.m. of cutter
= feed in inches per minute

Positive or Negative-rake Cutters.—A comparatively new development is in the use of milling cutters with teeth having a negative rake, as in Fig. 1. The primary object of this was to protect the cutting edges of the carbide cutters, which are hard and brittle. Experience has shown, however, that this form of cutting edge produces a smoother surface than the positive-rake cutter, especially on steel. This is attributed to the action whereby the metal being pushed off acts as a burnisher on the surface while the positive-rake edge tears the metal away from the surface beneath. The power required for this method of cleavage seems to depend on the comparative tensile and shearing strength of the metal being cut, but it is greater than with positive-rake cutters.

TABLE 1.—RECOMMENDED CUTTING SPEEDS FOR STEEL

Brinell hardness	Cutting speed, ft. per minute		Typical material
	Average	Limits = 10 per cent of average	
110	750	675–825	S.A.E. 1020
165	630	567–693	S.A.E. 1112
180	600	540–660	Annealed
200	570	513–627	Alloy
220	540	486–594	Steels
250	500	450–550	
300	450	405–495	Hardened
325	425	382–468	Alloy
350	400	360–440	Steels
400	360	324–396	

Negative-rake cutters are being used extensively on steels and the harder metals, but positive rake seems to be found best for aluminum in its various alloys and for magnesium. Suggestions as to angles of both the cutting edge and the helix of the blade

are given herewith. Tables 1 to 5 and the explanatory data are recommended by the Cincinnati Milling Machine Co.

The following general rules for choice of speed should be observed:

1. *Never* start a job without first determining the hardness of the material; for if a high cutting speed is used on a hard steel that is presumed to be soft, the carbide may fail instantly.
2. On a new job, start with average recommended cutting speed.
3. If cutter sparks prematurely, reduce cutting speed toward lower limit.
4. Where fine finish is required, use higher speed limit.
5. Where maximum life of cutter is desired, favor lower speeds.
6. If carbide edge begins to fail rapidly by abrasion, reduce speed toward lower limit.
7. If carbide edge begins to crater prematurely, increase cutting speed toward higher limit.

TABLE 2.—RECOMMENDED FEED PER TOOTH FOR STEEL

Type of Milling	Feed per Tooth
Face	0.006–0.012
Side or straddle	0.008–0.012
Slab	0.008–0.012
Slotting	0.006–0.010
Saw	0.003–0.006

General rules for choice of feed are as follow:

1. The maximum feed that can be used will be determined either by the power available in the machine, by the rigidity of the cutter, work, and fixture, or by the finish required. Check these items before starting a job.
2. Select the feed per tooth from Table 2 and remember that for shallow slotting cuts, etc., the maximum thickness of the undeformed chip may be only 10 to 50 per cent of the feed per tooth. Wherever possible therefore, on such cuts, use the upper limit given in this table.
3. If carbide begins to fail rapidly by abrasion, increase the feed per tooth.
4. If carbide begins to crater too rapidly, reduce the feed per tooth.

Number of Teeth in Cutter.—The number of teeth in the cutter should be selected in accordance with the power available

on the machine (or the maximum permissible power due to limitations of cutter or workpiece), using the formula:

$$T = \frac{HP \times K}{d \times w \times f \times N}$$

where T = number of teeth in cutter
HP = horsepower available at cutter (or maximum permissible power)
K = metal removal factor with dull cutter, in cubic inches per minute per horsepower
d = depth of cut, in inches
w = width of cut, in inches
f = feed per tooth, in inches
N = r.p.m. of cutter = $\frac{12S}{\pi D}$ (where S = recommended cutting speed in feet per minute and D = cutter diameter in inches).

This will permit full utilization of the power of the machine, wherever permissible, while keeping the feed per tooth and cut-

TABLE 3.—RECOMMENDED MILLING CUTTER ANGLES FOR STEEL

Type of mill	Work material	Axial rake, deg.	Radial rake, deg.	Corner angle, deg.	Corresponding true, rake, deg.
Face or side	Hard steel (or general purpose)	−10	−10	30–45	−13 to −14
Face or side	Soft steel (under 180 Brinell)	− 5	− 5	30–45	− 7
Slotting	Hard steel (or general purpose)	− 5	−10	.....	−10
Slotting	Soft steel (under 180 Brinell)	0	− 5	.....	− 5

TABLE 4.—RECOMMENDED CARBIDES FOR STEEL
(General purpose, for depth of cut = 0.040 in. or greater)

Work material	Sintered carbide			
	Carboloy	Kennametal	Vas Ramet	Firthite
Steel, 100–400 Brinell	78-B	KM	EM	TA

ting speed in accordance with the recommended values. Average values of the factor K for true rake angles of -10 to -14 deg., for the recommended speeds and feeds, and including a 25 per cent allowance for dulling of the cutter, are given in Table 5.

TABLE 5

Brinell Hardness	K (dull cutters)
100	0.80
150	0.70
200	0.65
250	0.60
300	0.55
400	0.50

Face and Slab Milling.—Surfacing in the milling machine was originally done by slab milling, as in Fig. 2, where the work was fed under a cutter having teeth on its circumference. This is still done in many kinds of work. Originally the work was fed against the cutter so that any looseness in the table or its feed would be forced away from the cutter; otherwise, the action of the cutter tends to draw the work under it and the cutter climbs on the work and may easily injure both the work and the machine.

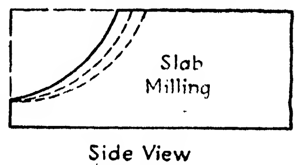


FIG. 2.—This shows how the chips in slab milling vary in thickness.

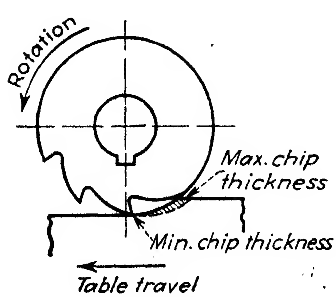


FIG. 3*a*.—Milling *against* the feed—called "conventional," "up," or "out" milling.

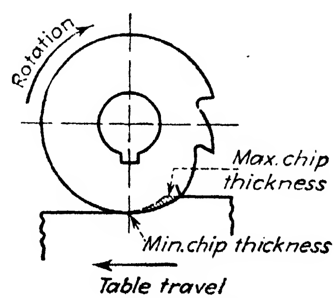
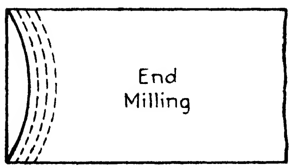


FIG. 3*b*.—Milling *with* the feed—called "climb," "down," or "in" milling.

Experiments have shown, however, that this climb method of feeding the work has distinct advantages. This may be shown by studying Fig. 3*b*. It will be seen that the old method of

forcing the work against the cutter makes the cutting edge scrape the bottom of the cut until the cutter gets "bite" enough really to begin to cut. In other words, the cut begins with no appreciable thickness of chip and ends with a chip the thickness of the feed per tooth. The difference in the two methods of forming the chip can be seen in the two illustrations.



Top View of Vertical and Side View of Horizontal Cutter

FIG. 4.—Chips taken in end milling are more uniform in thickness, depending on the relation between the diameter of the cutter and the width of the work.

With the climb or down feed, as it is now called, the cutting edge starts with a positive thickness of chip which grows thinner as the cutting edge reaches the bottom of the cut. This method of feeding, however, requires a machine with no loose joints and with a positive feed that will not be drawn under the cutter by the action of the cutting tooth. Modern machines now operate under these conditions, and this method is fast becoming standard for slab milling.

These two methods have been designated as "conventional" and "climb" feeds. But, since the old method is likely to become obsolete and the climb feed to become the usual one, it is felt that a positive name should be given to each method. The present solution seems to be to call them "down" and "up" feeds, which should be clear to all familiar with machine-shop work. There is, however, a possibility that the terms "in" and "out" may become standard; this refers to the surface of the work in slab milling. "In" milling would be climb or "down," and "out" milling would be the old method or up milling. On face milling where the cutter completely covers the work, we have both in and out milling.

There is a trend toward end or face milling instead of slab milling and here we have an entirely different condition which is shown in Fig. 4. Here the chip is more uniform in thickness unless the width of the work and the diameter of the cutter are the same, and some problems of the other method are eliminated. The relation between the diameter of the cutter and the width of the work is important.

Although face milling or end milling first came into use on milling machines with vertical spindles, the same method can be

used on either vertical or horizontal machines. The verticals do have certain advantages for work of this kind; the two main ones being that the work is visible to the operator and that the pressure of the work is down on the work table instead of being at right angles, as on the horizontal machine.

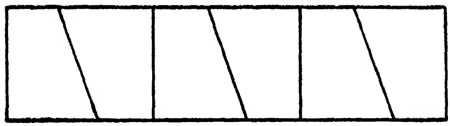


FIG. 5.—Flat fly cutters made from steel $\frac{1}{4}$ by 2 in.

Fly Cutters.—Fly cutters have been used for many years. One of the oldest and simplest forms of fly cutter was designed many years ago for use in milling brass hexagon nuts. It was made from flat tool steel $\frac{1}{4} \times 2$ in. and cut from the bar as shown in Fig. 5. This saved steel by alternating the way in which the cuts were laid out. When cut with a cold chisel,

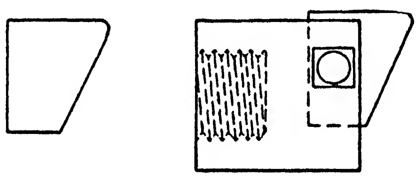


FIG. 6.—Finished cutter and its holder.

more grinding had to be done than when cut with a hack saw. But since the only cutting edge is at the point, this was not a serious matter. When properly shaped, hardened, and ground with a rounding corner or point, these cutters would leave a very smooth milled surface on the brass nuts. With a little judicious use of the oilstone on the cutting corner the finish was remarkably good. The finished cutter and its holder are shown in Fig. 6.

The first milling cutters had their teeth spaced closely together, but the modern tendency is to have few teeth and run them at higher speed. The fewer the teeth the more room there is for chips and the less difficulty in grinding them so as to have each tooth do its share of the work. On the softer metals, however, fly cutters with one or two teeth are doing excellent work in many places.

Figure 7 shows a two-toothed fly cutter used in milling a duralumin forging. A Milwaukee high-speed milling head is

mounted behind the bed of an old engine lathe and the work mounted on the lathe carriage. This is in the shop of the Intercontinent Aircraft Co. The cutters are held with headless

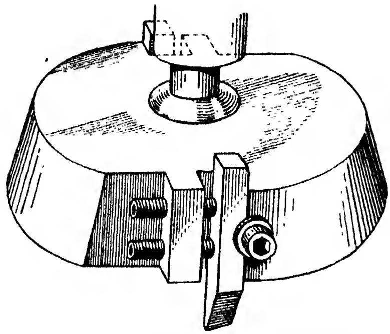


FIG. 7.—Two-toothed fly cutter for milling duralumin.

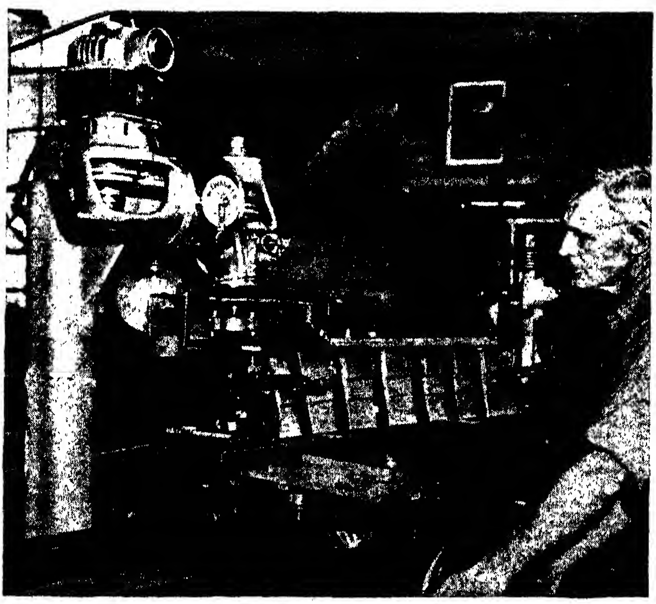


FIG. 8.—Safety-glass protection on a fly-cutter job.

setscrews as shown and run at a speed of about 2,000 surface feet per minute. The work is fed by the regular carriage feed at the rate of 2½ in. per minute. The roughing cut is 0.015 in. and the finishing cut 0.005 in. The tool bits are tungsten carbide

and give a mirror finish when properly honed. The tolerance is plus or minus 0.001 in. Safety-glass protectors allow the workman to watch the cutter without fear of chips, as seen in Fig. 8. Note that the milling head is mounted on a welded column back of the lathe.

Another fly cutter is seen in Fig. 9 which shows only one of the two blades. Figure 10 shows both blades set up in the machine. The surplus metal left between the blades by these cutters is removed by the cutters, seen in Fig. 11. A pair of cutters with carbide inserts machine the blades of an impeller for a supercharger of an airplane engine. These fly cutters have been found superior to the regular type of straddle mill for this particular job.

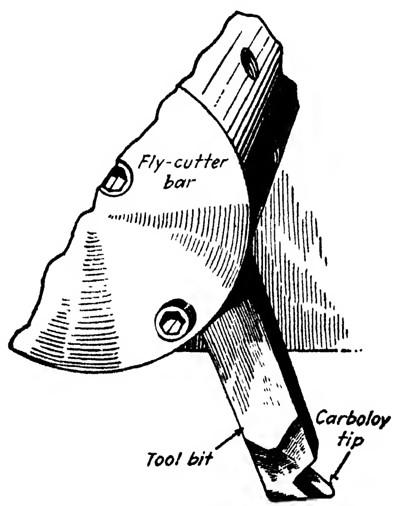


FIG. 9.—One blade of a fly cutter for supercharger impellers.

Fly cutters can be made quickly and at much less expense than the regular type of milling cutter for the same work. Great care should be taken, however, to see that they are held very securely in the cutter head. The whole cutter head must also be carefully balanced to prevent vibration. In some cases it is deemed advisable to have a positive lip or recess to take the centrifugal stress instead of depending on the grip of the setscrew. The speed at which these cutters must be run to secure best results makes them dangerous unless they are securely anchored in the body of the cutter. At extreme speeds the cutter shanks are welded to the body to ensure safety.

Another fly cutter is shown in Fig. 12. This is one of a pair used in place of the usual straddle mill seen in Fig. 13. They are much less expensive to make than large milling cutters of the conventional type and do excellent work. It will be noted that the cutters are set 90 deg. apart so as to divide the impact of the cut. In work of this kind it is much better to use a fairly heavy flywheel to ensure a smooth action of the machine and to

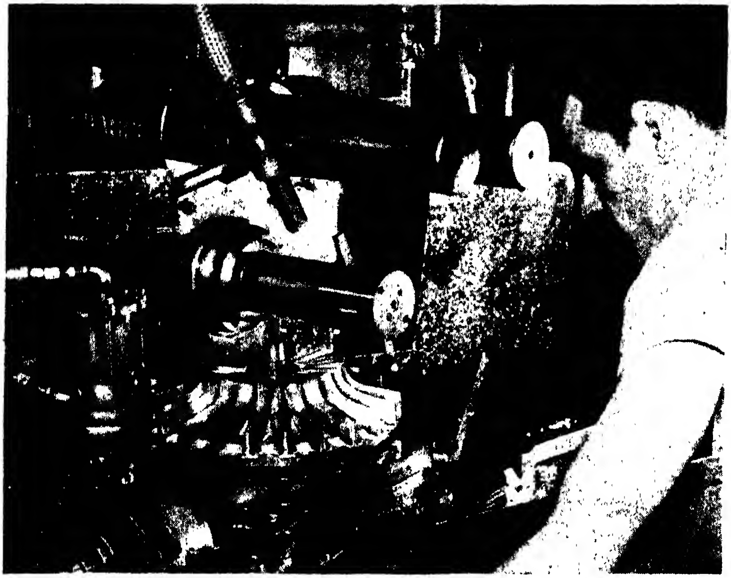


FIG. 10.—The fly cutter in position.

FIG. 11.—A pair of fly cutters to cut out surplus metal.

even up the load on the motor. Flywheels are highly desirable in all work of this kind, preferably as near the cutters as possible.

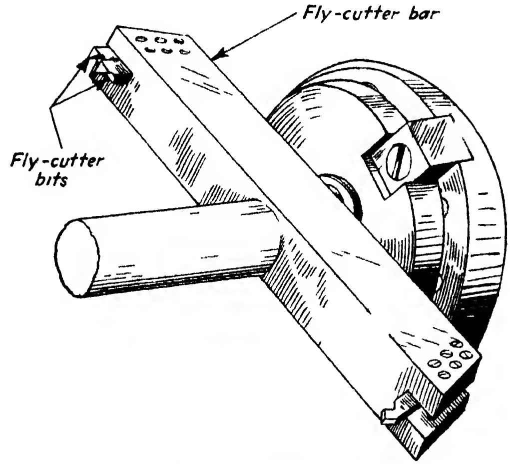


FIG. 12.—Details of one of a pair of fly cutters used as straddle mills.

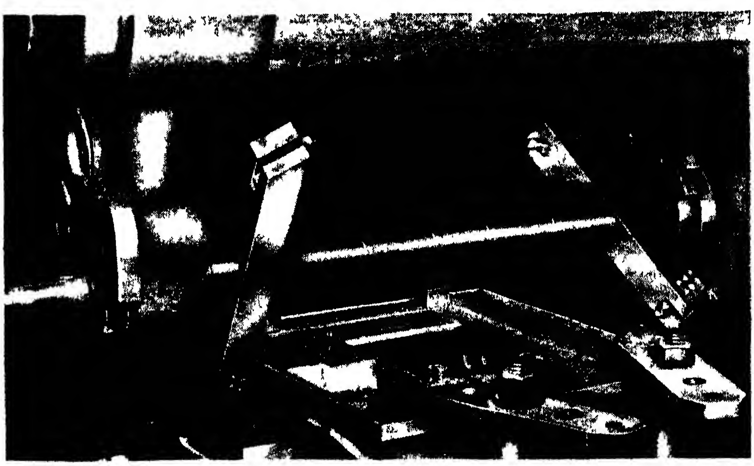


FIG. 13.—The pair of fly cutters on the straddle-mill job.

Milling with Fly Cutters.—Although the fly cutter was originally an emergency tool, the trend toward very high cutting speeds and a better understanding of the necessity for definite chip thickness, which means the feed per tooth, have made it a standard tool in many cases. It was probably the late A. L.

DeLeeuw who first advocated the use of milling cutters with fewer teeth and increased chip space. Present practice is to have still fewer teeth, even for steel; for aluminum and magnesium, cutters with one and two teeth are now common.

Fly cutters are particularly useful on special jobs where but a few pieces are to be made. They are inexpensive as compared with the multitooth cutter and can be made very quickly for the emergency job. In some cases it is possible to use two cutters, set one behind the other, so that the first can remove part of the metal and the second can take the remainder.

Although most fly cutters have but a single point and are used solely in facing off work, they are sometimes used to give a formed surface of special contour. In this case the desired shape is carefully laid out and a templet made to ensure the cutter's being of just the proper shape. Then the cutter is formed to fit the templet and, after hardening, is ready to go to work. The cutter in this case resembles the regular formed cutter used in screw machine work to secure special shapes on turned work. Such cutters secure very satisfactory formed surfaces when used with care and at proper speeds and feeds.

By holding such a cutter in a fixed downward position on the milling machine spindle and feeding the work under it by moving the table, it becomes a formed planer tool and can be used as such in an emergency.

Form Cutting in Hand Milling Machines.—Interesting examples of how forms can be machined on a hand milling machine are given by W. H. Nichols and Sons. The operation is chamfering the ends of pieces of different shape and utilizes a guide roller between the two cutters that cut the chamfer on each side of the piece.

The milling head in this machine moves vertically on the column. It is normally moved by means of a lever under control of the operator, or it can be left free to move of its own weight should this be desirable, which is seldom the case. In this case the operator controls the head so that the guide roller, which turns freely on the cutter arbor, contacts the surface it is desired to follow.

In Fig. 14 the work is held in a simple fixture mounted on the milling machine table. Shaft *A* is supported in the frame shown and is turned by handle *B*. The work in this case is held by a

screw with a handle C to lock it easily in the end of shaft A. The illustration also shows the end of the work to be chamfered and the milling cutters with the guide ring between them.

In Fig. 15, as the cylinder A is moved back and forth, the head rises between X and Y permitting the cutters to follow the work. When the cut is completed, the ring rests on the work as shown in Fig. 15.

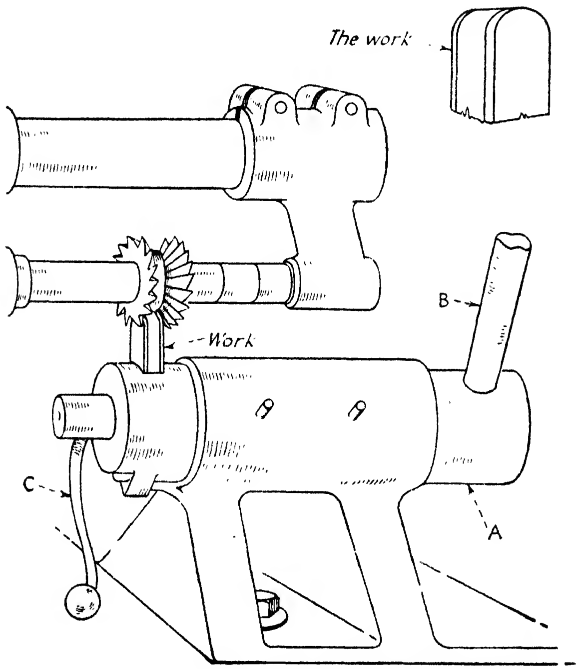


Fig. 14.—Form milling in a Nicholls' hood machine.

Figure 15 shows a cross section of a different job that can be done in the same way. The guide roller keeps the milling cutters in proper relation to the work so that the chamfer will be the same depth all the way around the piece. Here the work is rotated in the same fixture as in Fig. 14. The dotted lines indicate the different positions of the work.

An outline view of the way in which the operator utilizes both hands on the operation is seen in Fig. 16. One hand controls the work and the other the head of the milling machine. A few of the shapes that can be chamfered in this way are shown in Fig. 17.

Another adaptation of the hand miller is seen in Fig. 18 where it is being used in contour milling. Here the guide roller *A* runs free on the milling cutter arbor and is kept in contact with

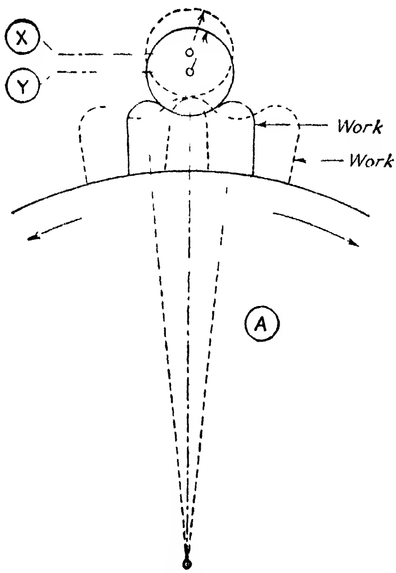


FIG. 15.—Guide rollers and work.

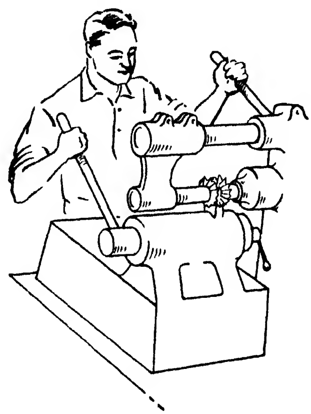


FIG. 16.—How the operator uses both hands.

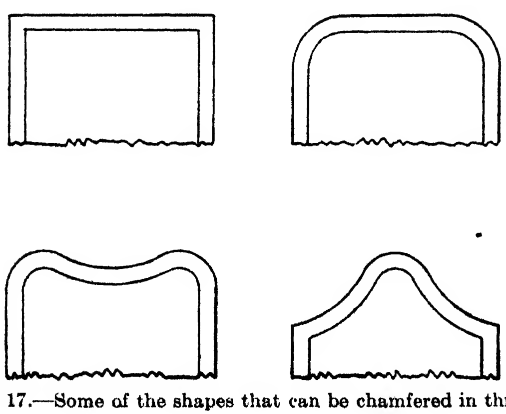


FIG. 17.—Some of the shapes that can be chamfered in this way.

the form *B*. The cutter duplicates the form on the work *C*. In Fig. 19 the follower or guide roller is mounted on an extension of the overarm of the machine, and the guide is located at the

proper distance from the cutter spindle. The work B is supported on the ledge A. The former is at C. The operation of the machine is the same as in the previous examples. Still

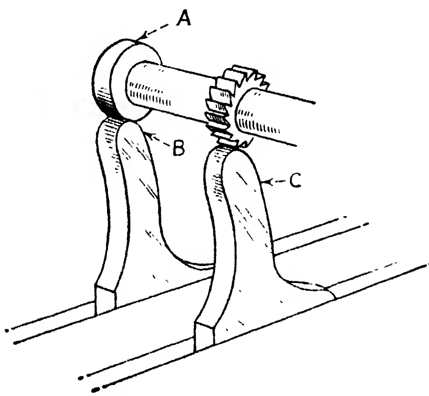


FIG. 18.—Another method of using a guide roller.

another example is seen in Fig. 20. Here the former B is at the end of the vise that holds the work C. The guide roller is at A.

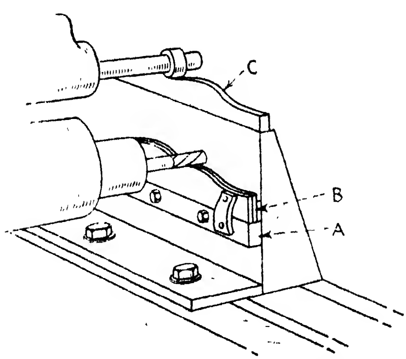


FIG. 19.—Here the follower is mounted on an extension of the overarm.

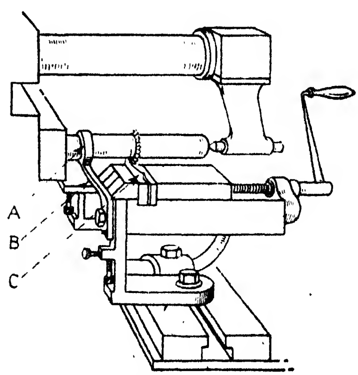


FIG. 20.—Still another way to use a guide and a follower.

Although some might consider these as makeshift operations, this is not necessarily the case. There are many operations where a good hand miller with a well-trained operator, man or woman, is the most economical method of machining. Although an automatic machine does not require constant attendance

by an operator, it may easily happen that the machine overhead chargeable to it and its maintenance will make the operation cost more than that done on a hand miller. Many are too apt to overlook the fact that often direct labor is the cheapest thing in the shop.

There are of course many jobs where the automatic milling machine pays good dividends, otherwise so many of them would not be found in various shops. But the average shop will find

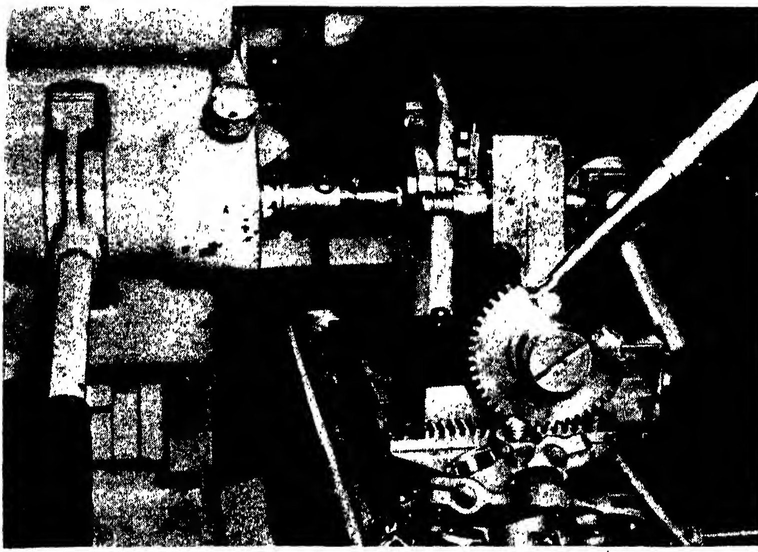


FIG. 21.—Another setup for a special motor job.

the hand miller a most useful and economical machine for a great variety of work.

Another Hand Miller Job.—By utilizing an old Kent-Owens hand miller, Orion N. Briel, a machinist in the plant of the Lycoming Motor Co., prevented delay in waiting for a new machine and also reduced the time allotted to the job of milling an oil slot in the rocker arm shown in Fig. 21. Both the fixture and several rocker arms are shown. More details can be seen in Fig. 22.

After the rocker arm is clamped in place, the fixture is moved forward on the base by means of the rack and pinion shown. This moves up against a stop. Then the head is moved down to

cut the oil slot shown in the rocker arm on the table. This replaced a solid fixture on the table and thus reduced the time required by 25 per cent.

With this kind of fixture, accuracy is built into the fixture itself and does not depend on the machine. This was important in the case under consideration as the machine was old and not worth rebuilding, nor could a new machine be secured owing to the war demand.

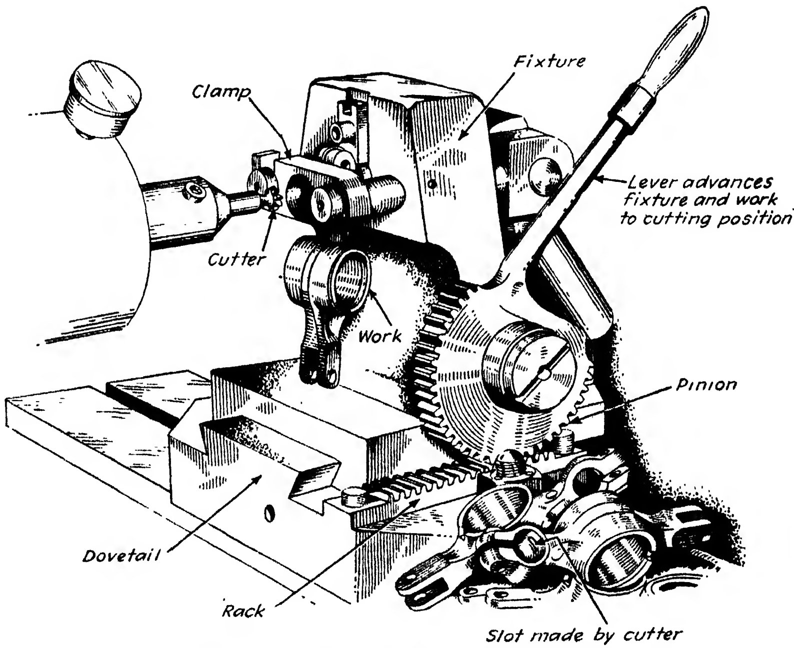


FIG. 22.—Details of the setup in Fig. 21.

A Large Face Mill or Rotary Planer.—The Joshua Hendy Iron Works built engines for Liberty ships, some of which were two and one-half stories high and weighed 274,000 lb. Facing both ends of the columns that supported the cylinders was one of the problems. The lower flange was 36½ by 31½ and the upper end nearly the same dimensions. The distance between the flanges was 13 ft. 1 in., and the tolerance was 0.001 in.

The first of these columns were machined on open-side planers, but it was felt that a milling machine would be better. So the engineers built a machine from scrap parts and from some of the

castings used in the engine itself. The cutter end is seen in Fig. 23 and a close-up of the cutter in Fig. 24. Stellite tips were used. The cutter head is driven by a 15-hp. d.c. motor rescued from the scrap pile. It drives through two stages of reduction gearing which gives a 200 to 1 reduction ratio. A rheostat pro-

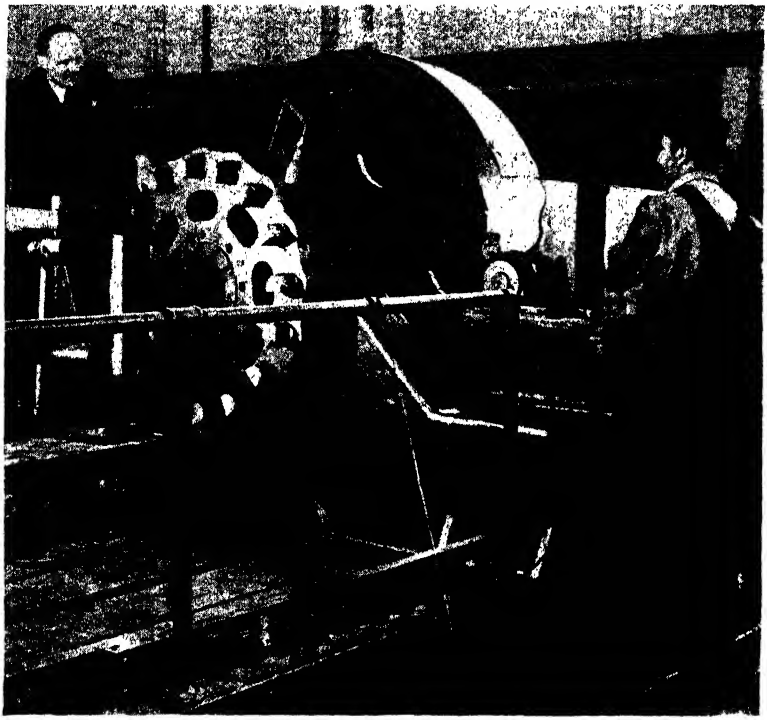


FIG. 23.—Large face mill for Liberty-ship engine work.

vides motor speed variations from 300 to 1,200 r.p.m. Between the motor and the first pinion is a Brown-Lipe truck transmission giving a 2 to 1 reduction ratio. The first pinion of the main reduction gear is keyed to the slow-speed shaft of the transmission.

Instead of the usual bedplate, there is a heavy concrete foundation which supports the whole machine and saves a large tonnage of cast iron in the construction. The bull or main drive gear is mounted in an engine bed from a Liberty ship, and the shaft is a part of the ship's crankshaft. The bearings are also Liberty ship engine parts.

Two types of ways were used to maintain close alignment between the carriage and the cutter head. One is in the form of a channel with rollers that fit this section, to absorb the vertical thrust. The other is a V-shaped way in which tapered rollers take the horizontal thrust. Both rails are 20 ft. long and have leveling blocks and wedges for vertical adjustment. Adjusting screws are also provided for horizontal alignment. As no

FIG. 24.—Close-up of milling cutters at work.

adjustments have been necessary since the machine was installed, its rigidity seems to be unquestioned.

A $1\frac{1}{2}$-hp. U.S. Varidrive motor turns a nut which moves the table along the screw under the bed. Table travel varies from $\frac{3}{16}$ to $\frac{3}{4}$ in. per revolution of the cutter which makes the feed from $\frac{9}{32}$ to $4\frac{1}{2}$ in. per minute. This range of feed takes care of the variations in the hardness of the castings. The screw, which remains stationary during the feeding of the table, rotates for rapid return or to bring the table to a new cutting position.

The cutter head is a massive casting of Meehanite. Sixteen $3\frac{1}{2}$-in. holes are provided for cutter holders, these being on a $37\frac{1}{2}$ diameter circle. The 6-in. thickness of the cutter head gives a rigid support to the shanks of the cutters, which project

4 in. when new. The cutting is done by $\frac{1}{2} \times 1$ in. Stellite tips brazed to the cutter shanks. Two cutter heads are provided so that the spare head can be put in place when cutters need regrinding and so prevent the machine's standing idle except for the time required to change heads.

Cutters are ground on a special machine, part of which is seen in Fig. 25. A high-pressure cylinder of a Liberty engine

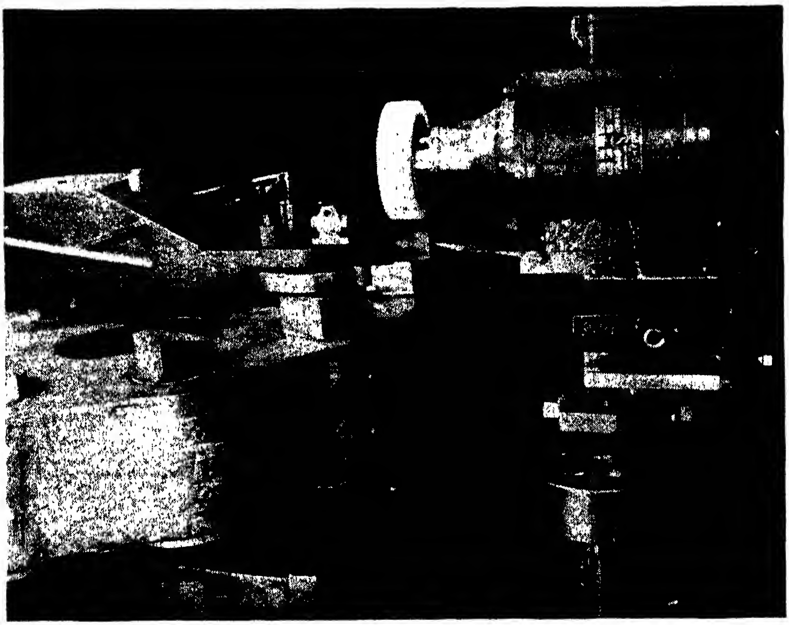


FIG. 25.—Special grinder setup to keep milling teeth sharp.

forms the base of the machine. Part of a thrust bearing shaft centered in the cylinder casting aligns the cutter head. Calibrated scales on the grinder show the relief angles for grinding the teeth to ensure uniformity of performance, which has been highly satisfactory. The grinder was very near the milling machine and time lost in sharpening the cutter blades was reduced to a minimum.

Fixtures with Target Gages.—Before work is started on any casting, it is important to know that it is true enough to pattern to have all the finished surfaces clean up to proper size when it is machined. For this reason, castings are frequently inspected

by gages of various kinds when they are received from the foundry and before they go the machining floor at all. As a double check on this, many fixtures are made with target gages to ensure that there is sufficient metal before starting work on the piece. A few gages of this kind, both with and without fixtures, are shown.

Figure 26 shows a headstock casting in position on a boring machine table being checked to see that holes in both directions

Fig. 26.—Using target gages to check castings before starting work.

are right and that the surface on top is high enough to clean up. In addition, there are two gages shown under the milling cutters to be sure that these are at the right height to surface the various pads correctly. The method of holding the work on the table is also shown. These show Lucas shop practice.

Somewhat similar gages are shown in Fig. 27. Here the large target with the white cross bar is held on extensions from the base of the block on which the work is clamped. This is another view of the piece shown in the previous figure.

The next three illustrations show a fixture and target gages for holding and checking a machine casting for machining on a boring machine. The fixture is a simple base plate furnished with hardened pins on which the casting rests. Suitable clamps hold the casting from the top and sides. The plate on top in Fig. 28 checks the outer contour of the upper face with relation

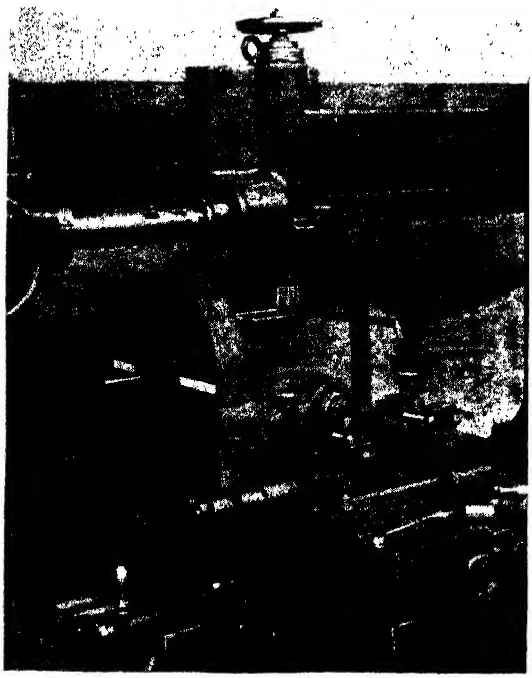


FIG. 27.—Another example of using target gages.

to the bearing projections on the inside. Small angle pieces welded to this plate locate it by these projections.

At the left is a support carrying two targets that show whether or not there is metal enough to clean up when these holes are bored. Each target disk has four openings around the edge so that the amount of metal all around the hole can be seen.

Figure 29 shows the target gage at the other end of the casting, which has a fourth hole to check below the other three. This shows the substantial construction of these gages and also of the clamps by which the work is held. With the front target gage

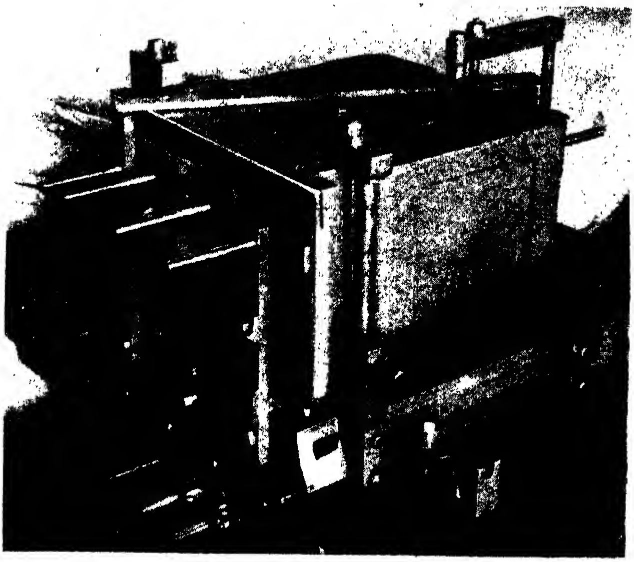


FIG. 28.—Fixture and target gages used in setup.

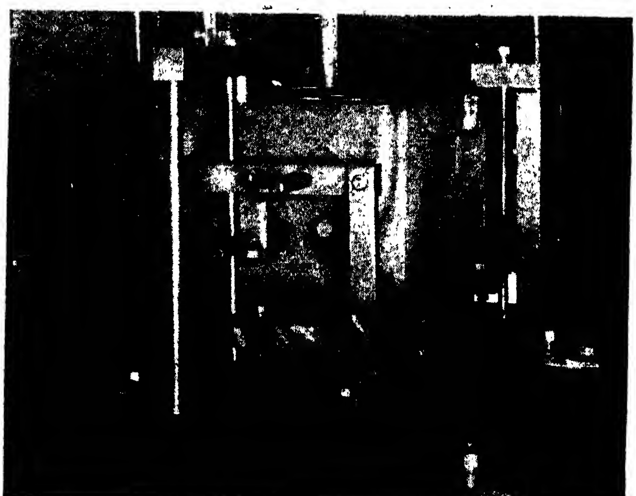


FIG. 29.—Checking a fourth hole in the casting.

removed and the top plate out of the way, the front end is milled by two cutters. The small cutter finishes the top and side edges of the casting and is then removed. This leaves the large face cutter in position to surface the front area of the casting at a rapid rate. Figure 30 shows the horizontal surface being milled by the small cutter of the pair. This is removed for facing the end, the large cutter being used for that purpose.

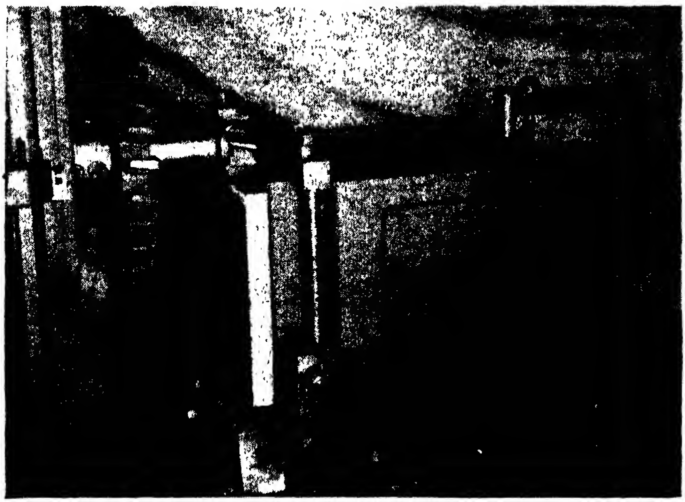


Fig. 30.—Using a small milling cutter. The large cutter is for face milling.

Some Special Milling Machine Setups.—Figure 31 shows a Fray All-Angle milling machine set up for cutting a four-fluted end mill.

The work illustrated is done while chucked in a universal dividing head for indexing of the job to the four positions required in the fluting operation. This is a special dividing head which is very convenient for many unusual jobs. Chucks, end mills and cutters, offset boring heads and other tools are readily mounted in the spindle for their specific purposes.

Operation or adjustment of the ram that carries the milling head is by means of a ball crank at the front. The cross movement of the saddle in which the ram operates is controlled by the ball crank at the right-hand side, which is mounted on the end of the feed screw. Handwheel and crank are clearly shown. The movement of the ram is determined by the graduated dial on the

lead-screw shoulder, this dial reading directly in thousandths of an inch. A positive clutch with which the ball crank is provided is readily released to prevent accidental movement of ram and head.

As the turret head is graduated through 360 deg., milling, drilling, and boring can be done at any angle, either longitudinally

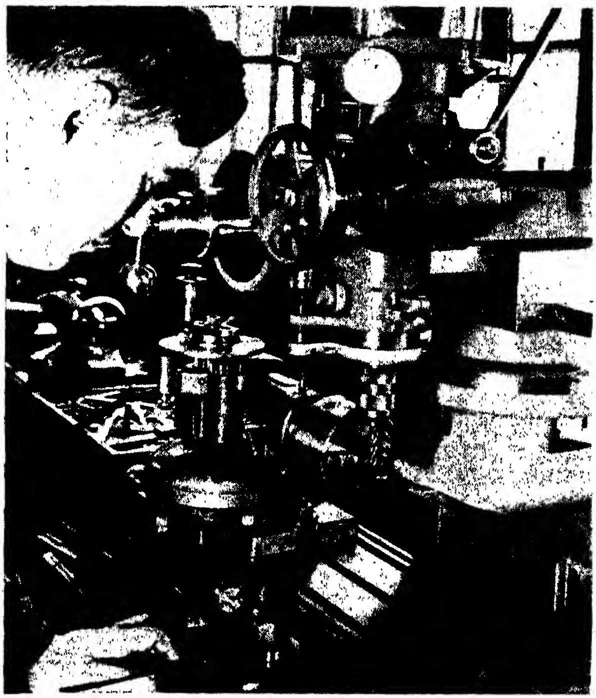


FIG. 31.—Fray All-Angle miller on a toolroom job.

by traversing the ram on the turret slide, or crosswise by operating the ram in its saddle. These two movements, when used in conjunction with the head (which can be set to operate at any of both angles in the vertical or horizontal planes), provide the toolmaker with a wide range of operation without changing the work setup. The value of this arrangement is fully appreciated by skilled workmen, who realize the advantages of securing the work in proper position at the outset and then carrying it through the necessary sequence without alteration of its original setup.

Figure 32 shows this miller on a permanent mold job. The work is secured in upright position on the table of the miller, where the entire face of the job is clearly seen by the operator, who has every opportunity for bringing suitable cutting tools to work on the cavity required. Manipulation of the head is

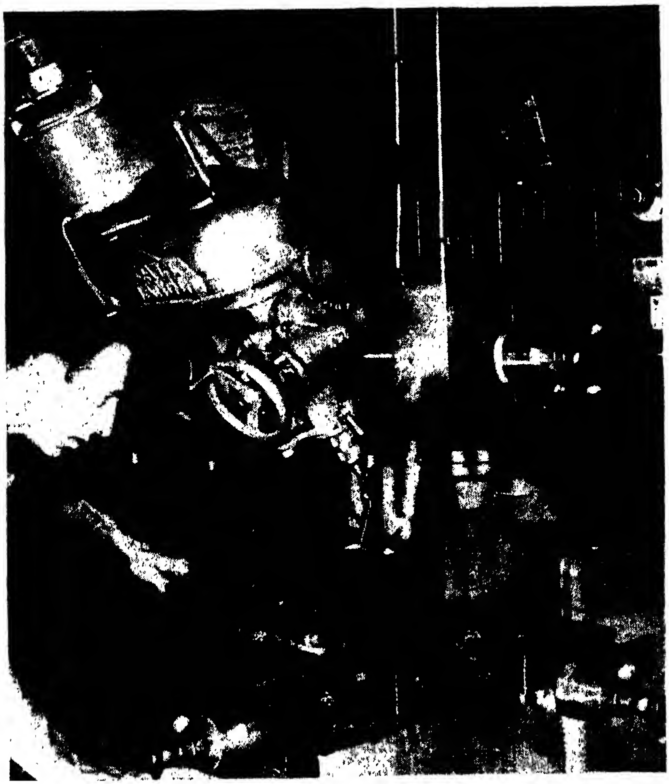


Fig. 32.—The same machine cutting out a permanent mold for castings.

readily accomplished, and the unusual setting required for this difficult piece of work is achieved with the closest degree of accuracy.

Feeding in all directions is necessary on the job, and these movements are available to exact tolerances. All micrometer dials and control handles for universal adjustments are conveniently located.

In Fig. 32a is shown a very compact and inexpensive setup for milling two strings of connecting rods at one setting. The

rods are supported by rods through the bores at the top and held against side motion by the rods shown. They are also clamped solidly against the end supports of the fixture and against each other.

Milling Radius Larger than the Cutter.—It is often desirable to mill a radius larger than the largest cutter available or a radius between two cutters in a toolroom. It is frequently possible to mill a desired radius by tilting the cutter the proper

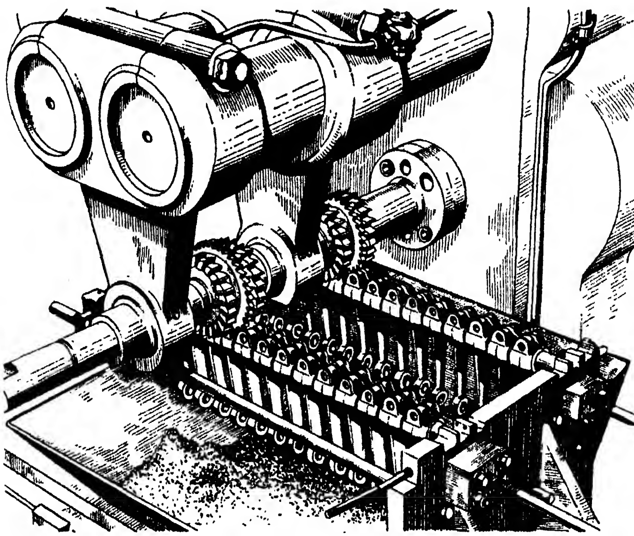


FIG. 32a.—Mass-production setup for milling connecting-rod ends.

amount, as shown in the illustration. Although a tilted cutter mills an ellipse instead of a true circle when used in this way, in many situations only a part of the arc is needed and the curve is near enough to answer the purpose.

With the cutter tilted 30 deg. as shown, it will mill an arc twice the diameter of the cutter. In all cases the "tilt height," as shown in Fig. 33, bears the same relation to the cutter diameter as the cutter diameter bears to the desired curvature. To find this ratio, divide the diameter of the cutter by the diameter of the desired curve. To get a 12-in. radius with a 6-in. cutter, divide 6 by 12, which gives 0.50 as the ratio. The accompanying table shows that the tilt angle must be 30 deg., as before stated. The table, which was worked out by P. W. Swain, editor of

TABLE FOR FIGURING ANGULAR TILT OF CUTTER

To get the ratio, divide the diameter of the cutter by the diameter of the desired curvature. Tilt spindle from the vertical by the angle tabulated opposite this ratio. This table is based on an ordinary table of sines

Ratio	Angle, deg.	Ratio	Angle deg.	Ratio	Angle, deg.
0.05	2.9	0.40	23.6	0.70	44.4
0.06	3.4	0.41	24.2	0.71	45.2
0.07	4.0	0.42	24.8	0.72	46.1
0.08	4.6	0.43	25.5	0.73	46.9
0.09	5.2	0.44	26.1	0.74	47.7
0.10	5.7	0.45	26.7	0.75	48.6
0.11	6.3	0.46	27.4	0.76	49.5
0.12	6.9	0.47	28.0	0.77	50.4
0.13	7.5	0.48	28.7	0.78	51.3
0.14	8.0	0.49	29.3	0.79	52.2
0.15	8.6	0.50	30.0	0.80	53.1
0.16	9.2	0.51	30.7	0.81	54.1
0.17	9.8	0.52	31.3	0.82	55.1
0.18	10.4	0.53	32.0	0.83	56.1
0.19	11.0	0.54	32.7	0.84	57.1
0.20	11.5	0.55	33.4	0.85	58.2
0.21	12.1	0.56	34.1	0.86	59.3
0.22	12.7	0.57	34.8	0.87	60.5
0.23	13.3	0.58	35.5	0.88	61.7
0.24	13.9	0.59	36.2	0.89	62.9
0.25	14.5	0.60	36.9	0.90	64.2
0.26	15.1	0.61	37.6	0.91	65.5
0.27	15.7	0.62	38.3	0.92	66.9
0.28	16.3	0.63	39.0	0.93	68.4
0.29	16.9	0.64	39.8	0.94	70.1
0.30	17.5	0.65	40.5	0.95	71.8
0.31	18.1	0.66	41.3	0.96	73.7
0.32	18.7	0.67	42.1	0.97	75.9
0.33	19.3	0.68	42.8	0.98	78.5
0.34	19.9	0.69	43.6	0.99	81.9
0.35	20.5				
0.36	21.1			1.00	90.0
0.37	21.7				
0.38	22.3				
0.39	23.0				

Power, gives both the ratio and the angle in degrees, which will be convenient for use with a milling machine head.

Cam Milling on Horizontal Boring Machine.—One of the many special jobs handled in a can machine factory is milling a drum cam known as a "topper cam" which is a casting about 9 in. in diameter. Figure 34 shows this being done on a Lucas horizontal boring machine. The total lead of the cam groove is

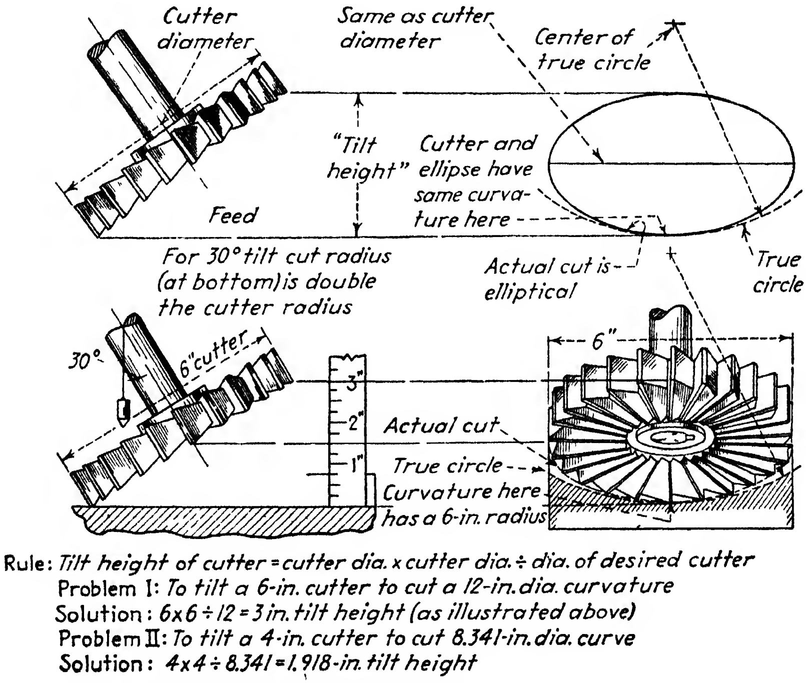


Fig. 33.—Milling a radius larger than that of the cutter.

3½ in. The cam groove being milled is 1½ in. wide by ⅞ in. deep. The cast drum-shaped body is cored for this groove channel to within ¼ in. of width, leaving sufficient metal for clean cutting of the end mill in producing the groove to the required width.

The rough milling leaves the cam groove 1/32 in. narrow, a special end mill that much under size being run through to remove the bulk of the metal. Then a 1½-in. mill is used to size the cam groove properly. In roughing out the stock, the

end mill is run at 140 r.p.m. and the finish mill at 173 r.p.m. The feed is at 0.018 to 0.032 in. per revolution.

The cam fixture has a worm and worm-wheel drive taken from the machine drive for revolving the work while at the same time it is fed longitudinally past the cutter in a forward and return movement by conforming to the control of a master cam held in uniform contact with a guide roll through the action of a counterweight at the front of the fixture.

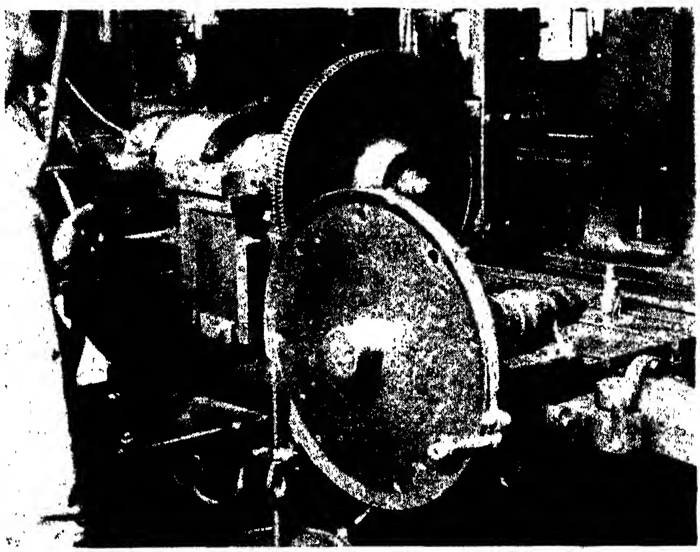


Fig. 34.—Milling a cam for a can-making machine.

Milling Heads on Various Machine Tools.—Ever since milling became one of the shop operations in common use, new uses have been found in connection with machines primarily built for other purposes. One of the first of such applications was probably the placing of a milling head on the cross rail of a planer so as to mill pieces larger than would go on the tables of milling machines built at that time. This gave rise to the building of the planer-type milling machines that now play such an important part in manufacturing.

These milling heads were originally driven by belts, but the development of the electric motor made the use of independent power possible in many kinds of machinery. The milling head

now carries its own motor and can be attached wherever it seems best.

Clark R. Pfeiffer, of the General Electric Company's plant in Schenectady, put a milling head with a 3-hp motor on the ram of a boring mill to handle a special job. This motor has gear reduction built into the housing and carries a 6-in. milling cutter, as seen in Fig. 35. It was devised for a special job that combined

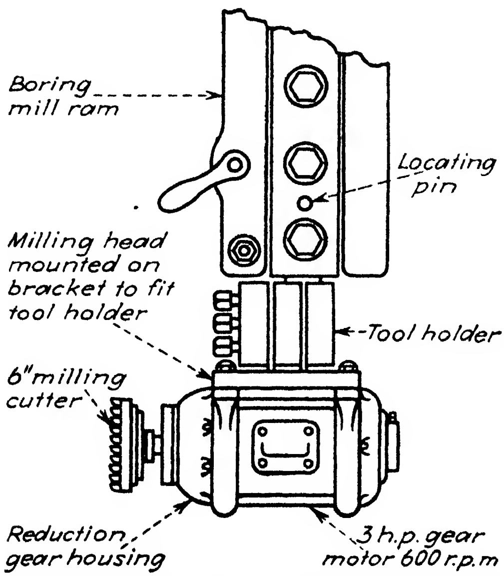


FIG. 35.—A motor-driven milling or a boring mill.

turning and milling some flat surfaces with special relation to the rest of the piece. So, after finishing the turning and boring work usual to the boring mill, the milling attachment is put on the ram and the flat surfaces milled in correct position. This saves moving the work and setting it up again on a milling machine.

It does not always pay to use a machine for two purposes, but in this case it was found to save time for both the men and the machines involved.

The Band Saw Saves Milling and Metal.—The Yale & Towne Mfg. Co. used a band saw to machine a lot of aluminum forged forks by the method shown in Figs. 36, 37, and 38. The outline of the slot was scribed on the forging. It was then clamped in a

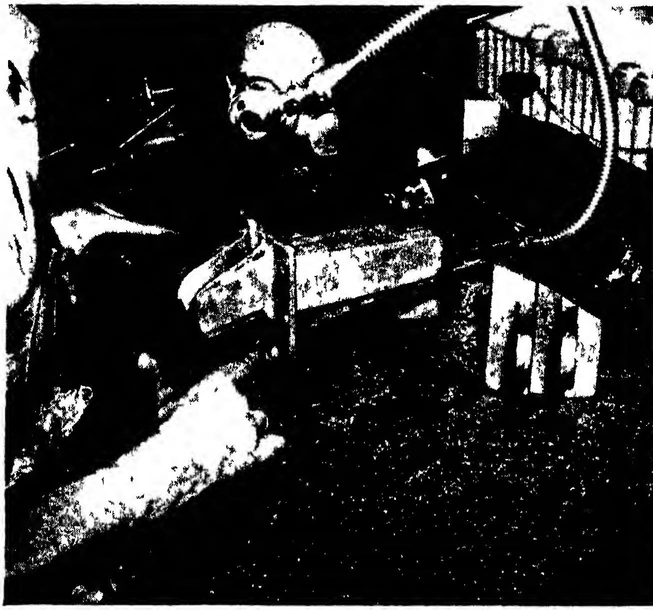


FIG. 36.—Band-sawing an aluminum forging for aircraft work

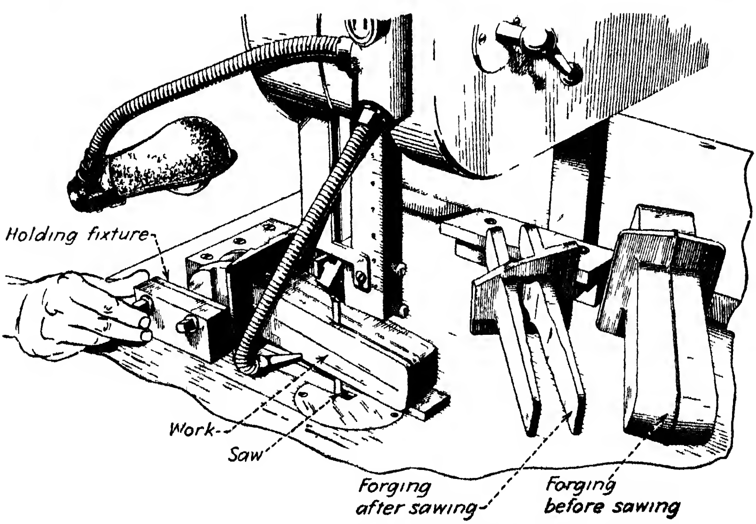


FIG. 37.—Details of the setup for band-sawing and the work done.

chuck or vise to hold it squarely and sawed out on a Do-All machine as shown. It will be noted that the slot has stepped sides. It would have required a 20-in. milling cutter of special form to cut this slot in the usual way. The finishing was done on an old profiling machine. Figure 37 shows details of the sawing operation.

In addition to permitting the use of simple and inexpensive machines and cutters, this method also saved considerable metal.

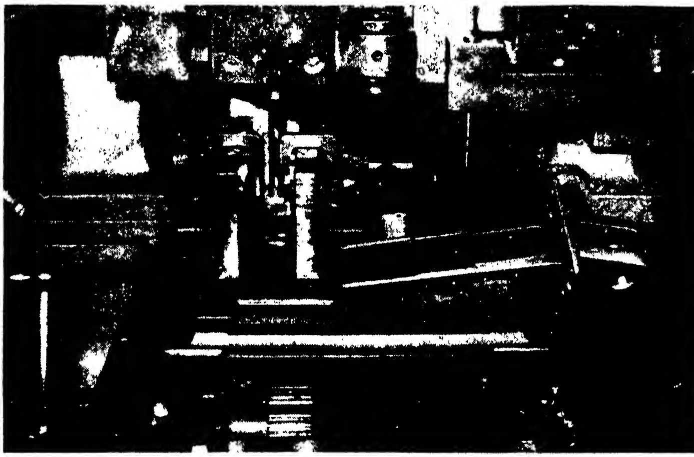


Fig. 38.—Finishing the fork by profile milling.

The metal cut out was in a solid piece and so worth much more as scrap than it would have been as chips from a milling machine. It also saved considerable time. There are many jobs where the band saw can save time in a similar manner.

After the main central part has been removed by sawing, the inside surfaces are finished to size by milling on the profiler as shown in Fig. 38. The former or templet is shown at the right and a finished fork in front of it.

Here again a carefully thought out plan aided production. To avoid the necessity of keeping the profile follower the same size as the cutter, the follower and the templet were made with tapered sides. Then, when the profiling cutter was ground down in sharpening, the tapered follower was raised enough to make up for the difference in diameter.

This combination of band-saw profiling was much faster than milling with a 20-in. cutter and also conserved metal by not

cutting it all up into chips. The same method could be used with steel as with aluminum.

Metal Sawing by Frictional Heat.—Under the guidance of Arthur A. Schwartz, chief tool research engineer of the Bell Aircraft Corporation, this company has developed some interesting practices in the cutting of metal with band saws. Using band saws designed for wood in order to secure the necessary speed they now run them at a minimum of 12,000 ft. per minute. The saws are enclosed in strong steel housings to protect the workers when the saws eventually break, as they do from the continuous bending at this speed.

Carbon-steel saw blades with a wide set and a soft spring temper are used. For ordinary work on thin materials, a saw with 10 teeth per inch is used, and for heavier materials a saw with 8 teeth per inch. It should be noted that the 10-tooth saw cuts faster. With a 10-tooth blade at 12,000 ft. per minute, 1,440,000 teeth pass through the kerf (or cut) every minute. This is 24,000 active teeth per second. With material 0.20 in. thick the tooth is in contact with the work for only 1/12,000 sec. At this speed the heat generated does not travel into the adjacent material to any extent.

Blade Speed Carries Heat Away.—Heat in the saw blade is spread over its entire periphery, and radiation and convection cool the blade for about 99.8 per cent of the time. Hence, although the points of the teeth are rubbed or burned quickly in this friction-sawing operation, the blade itself does not increase in temperature appreciably. The friction of the saw teeth on the metal being cut not only melts the metal but turns it into gas, as can be noted by the color of the flame under the sawing point. The speed is so fast that the heat is carried away before it can travel to the adjacent metal.

Since the friction sawing of metals with a band-saw blade depends upon the temperature developed by action of the blade rubbing on the material to be cut, and because variations in the hardness of the saw and of the material being cut do not affect the burning action appreciably, it is best to select a saw on the basis of its ability to stand the constant flexing around the wheels for the longest time. Experience shows that it is best to keep a wide set in the teeth to minimize side friction on the blade. It would be possible to use this blade without any teeth,

except for side friction in the kerf. With teeth cut in the blade, the kerf can be widened for the passage of the blade by the usual saw-setting method. Spaces between the teeth carry oxygen-rich air into the cut to ensure maintenance of the burning action.

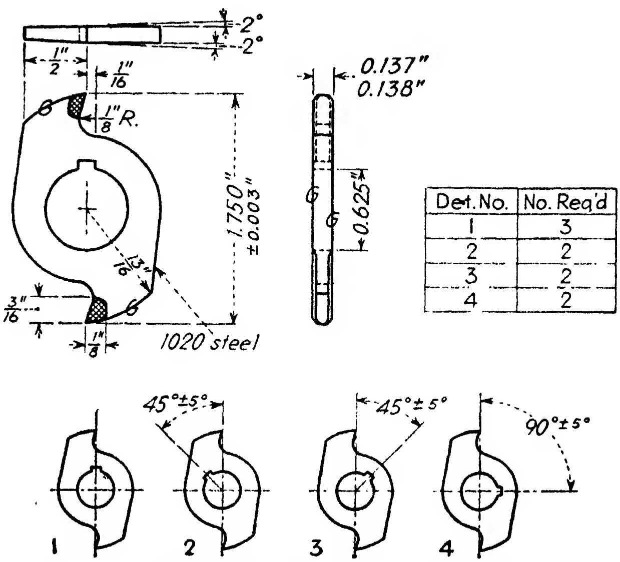
As the limit of thickness in the material is approached, there is difficulty in starting the cut. However, a thick piece can be tipped so as to present for an instant a shorter kerf. The flame will light up, and then the cut can proceed with ease. In cutting steel, the flame has a cobalt blue-white color, indicating that oxygen is combining with the iron. Harder steels have a higher coefficient of friction and therefore will cut more rapidly by this method. With other metals the speed of sawing and the thickness that may be cut with a given speed and power input vary considerably. In high-carbon steels, some of the surfaces near the edges may become hardened if insufficient feed is used. When proper feed and speed are maintained, this hardening should never exceed 0.001 to 0.002 in. in depth. Files have been cut without drawing their temper.

At the present time it is not possible to give definite information as to the type of saw to use for various metals, nor to develop a table of the most efficient speeds and feeds for the different materials that can be cut and for different thicknesses of these materials. Feed is measured by pressure against the blade, and this pressure is governed by the resistance of the blade to bending or buckling. A ½ in. wide blade, 0.025 in. thick, took 17 lb. pressure when sawing 5⁄16 in. thick armor plate. A ⅝ in. wide and 0.032 in. thick blade was used on the same material with 22 lb. pressure. The speed of cut resulting from these pressures was ½ in. and 17 in. per minute, respectively. The second blade also was used on ⅝ in. thick hard armor plate with 25 lb. pressure. In this case, the material was fed at 16 in. per minute. Hard steels 1¼ in. thick have been cut. Reports from other companies using this process and employing heavier saws with higher speeds, indicate that much heavier sections can be cut.

The most important feature of the process, when used in sheet metal, is the ease with which such materials can be cut. This is true whether the sheet rests on the saw table or is held by hand above the table. As the saw does not "grab" in the work, it is possible to trim irregularly shaped pieces easily and

rapidly when they are supported above the saw table by the operator's hands. In such operations the speed of cutting, that is, the rate of feed, is determined by the skill of the operator.

Low-cost Milling Cutters.—Airplane engine practice involves some difficult operations. Some of these are necessary for the lightening of the parts, others for aiding in cooling the engines which develop so much power in so little space. They all



Det. No.	No. Req'd
1	3
2	2
3	2
4	2

FIG. 39.—Cutters that saved money over standard types.

require special tooling, and this means cutters that must be kept sharp and replaced as often as necessary.

One job of this kind is the milling of the fins inside the pistons of the Pratt and Whitney engines. Some of these are being built by Chevrolet, who have developed some interesting cutters for this work. The same ideas can be applied in many other places.

The first cutters were made with six teeth in accordance with former practice. These dragged in the cut, overloaded the arbors, required frequent resharpening, and sometimes broke in the cut after a few pieces had been milled. So, following the later practice of using few teeth, cutters were made, as shown in Fig. 39, with only two teeth, the cutting edges being of carbide deposited on carburized bodies by gas welding. The bodies are

of S.A.E. 1020 steel, carburized for stiffness. These cutters cost $27 per set as against $108 per set for the six-toothed cutters formerly used. The spacing of the keyways shows how the teeth are staggered on the arbor.

These cutters are usually sharpened once for each shift, and the breakage has been reduced to a minimum. The tools cost one quarter as much as those which are replaced. The longer life makes them even more economical. There is also a great difference in the amount of money tied up in cutters.

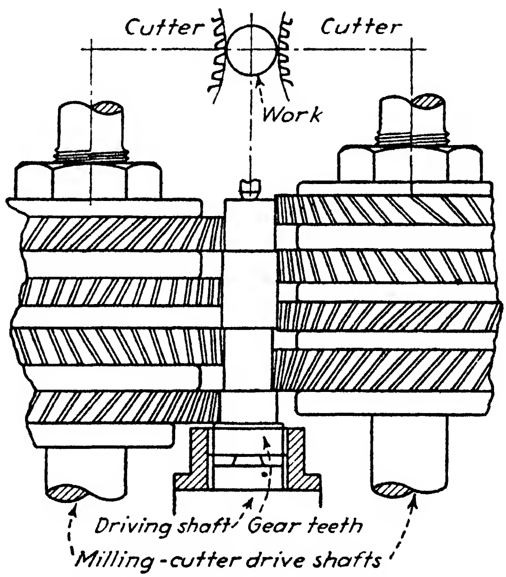


FIG. 40.—Machining transmission-gear blanks with two sets of milling cutters.

Turning Gear Blanks in a Milling Machine.—Figure 40 shows how transmission gears are rough-turned by milling instead of in a lathe. There are two spindles, each carrying a gang of milling cutters of varying diameters to give the shaft the shape desired. This method is known as "rotomilling." The rough shaft is fed in between the cutters and is then revolved one turn, completing the work. It said to be more rapid than a turning operation.

Milling Recesses in Die Blocks.—Recessing die blocks can be done in several ways. Metal can be removed by drilling, with an end milling cutter or by special devices, one of which is shown in Fig. 41. Profiling machines of various types are

largely used as well as special die-sinking machines of the Keller type, the Cincinnati Hydrotel, or some of the reproduction attachments such as the Turchan.

The device shown was made by Eric Myers, toolroom foreman of the Robert Mitchell Co., Ltd, Montreal. The supporting arms were welded to be anchored to the overarm casting as shown. At the lower end is a housing that carries the driving gears and the cutter at the outer end of the lower gear shaft.

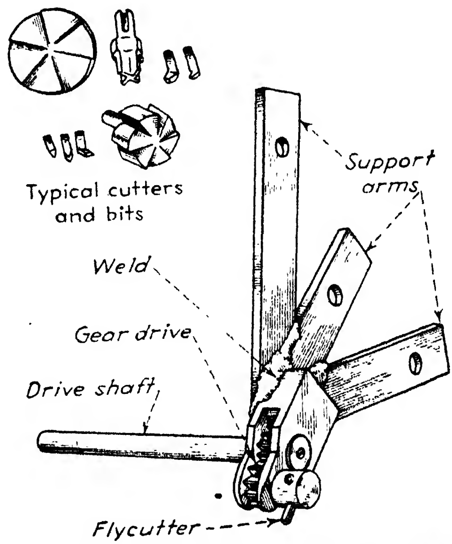


FIG. 41.—Fly cutter used in recessing die blocks.

The upper gear is driven from the milling machine spindle. The lower gear is mounted on a hollow shaft which carries the tool bit, or fly cutter holder, shown in place, or one of the typical cutters seen in the upper corner.

With the housing shaped as shown, radii can be milled out with centers only $\frac{1}{32}$ in. above the surface of the block being cut. It is also claimed that tolerances of 0.001 in. can be maintained.

Profiling.—The profiling machine is a type of vertical-spindle milling machine. In addition to having one or more spindles milling, it has a follower or profile spindle to be kept in contact with, and to follow, a form or pattern. With the form as a guide, the work table of the milling machine is moved both

crosswise and longitudinally to keep the follower in contact with the form as in Fig. 42. With a piece of work fastened to the milling machine table under the milling spindle and in the same relation to it as the follower is to the form or guide, the work will be milled to the same contour as the guide used. This means that the follower must be of the same diameter as the milling cutter or that allowance must be made for the difference. This ensures the surface on the cylinder head being milled without injuring any other part of it.

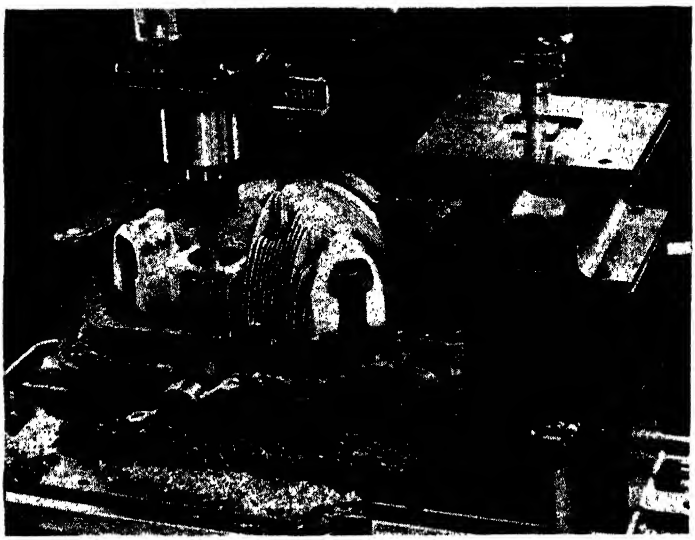


FIG. 42.—Surfacing a flange seat on an airplane engine cylinder. The guide plate and follower are at the right.

Profiling machines owe their development largely to the demands of gun and sewing machine shops in the late 60's and early 70's. Textile machine building shops also use them to some extent. The demand for thousands of duplicate parts for the war effort has greatly increased the use of these machines in recent years.

The original machines had but one milling spindle, but the demand for greater output led to the use of several spindles for milling cutters as seen in Fig. 43, which has four spindles besides the follower at the right.

The earlier machines also had hand-operated tables, but the later machines control the movement in both directions auto-

matically by means of hydraulic mechanisms which keep the follower in contact with the master form at all times. Some use electrical contacts to control the hydraulic mechanisms and have four milling spindles, as shown. This machine is known as the Hydrotel and is made by the Cincinnati Milling Machine Co.

FIG. 43.—Multispindle profiler cutting the packing groove in a Hamilton-Standard propeller hub.

There are also two or more devices available which can be attached to any vertical milling machine to make the table control automatic. These devices are very useful in duplicating drop-forging dies and similar work. In some respects they resemble the work done by the Keller engraving machines.

Many parts of irregular shape can be machined by broaching instead of by profiling. In fact the broaching machine has replaced the profiler in some operations. An example of this is the hub of a Hamilton air propeller where the scalloped contour around the bolt holes, formerly done by profiling, is now being done with a broaching machine.

Contours can also be formed with milling cutters shaped to the desired outline. In the case of the hub, however, the milling

cutter would have to be of such a large diameter as to make it impracticable. In other cases the formed cutter might be more economical. If, for example, a shop has a good supply of milling machines, it might not be advisable to invest in a broaching machine and the necessary broaches, even if the actual machining time would be considerably less. In too many cases management loses sight of the cost of machine overhead and the cost of special tools in the endeavor to save a little direct labor cost. Real economy is secured only when all the costs have been considered and balanced against each other.

Instances of this kind can often be found where a hand milling machine is more economical than an automatic machine on some simple operations. Low first cost of both machine and cutters, low power requirements, and small shop space all count in its favor. With a good operator the output is often astonishingly high. On the other hand, there are many operations where broaching is the only method to be considered.

Profiling too has many places that cannot be filled by any other method. Such a case is seen in Fig. 43 where a four-spindle Cincinnati automatic profiler is cutting a special packing groove in the faces of the mating surfaces of propeller hubs. With a form in place under the tracer at the right and two half hubs in place in the fixtures as shown, the narrow packing groove shown on the hub at the right can be milled in both halves of the hub at the same time. Because of the large diameter of the hub, only two can be machined at once, using only two of the four spindles of the machine.

About the only alternative to the profiler in such a case as this would be to use a steel templet to fit over the hub, with slots where the grooves are to be cut. It would be possible to cut these packing grooves with a small end mill in a vertical-spindle hand miller, with the cutter guided by the grooves in the steel plate. It is possible that a small portable electric drill might be used to drive the cutter, guiding it by the templet.

Of course the grooves could be cut by hand with a round-pointed cold chisel or cape chisel, either with or without the steel templet. But a templet would be necessary if the grooves were to match so as to hold the packing satisfactorily. Neither of these methods could be tolerated in the production of hubs of this kind.

Figure 44 is a good example of automatic profiling. Here four locking plates for knuckle or articulated rod pins for a seven-cylinder airplane engine are being profiled at the same time. The pattern is at the right below the follower, which is the same size as the milling cutters. A finished piece is shown at the right under the dial indicator. The locking plates are profiled on their entire outer surface.

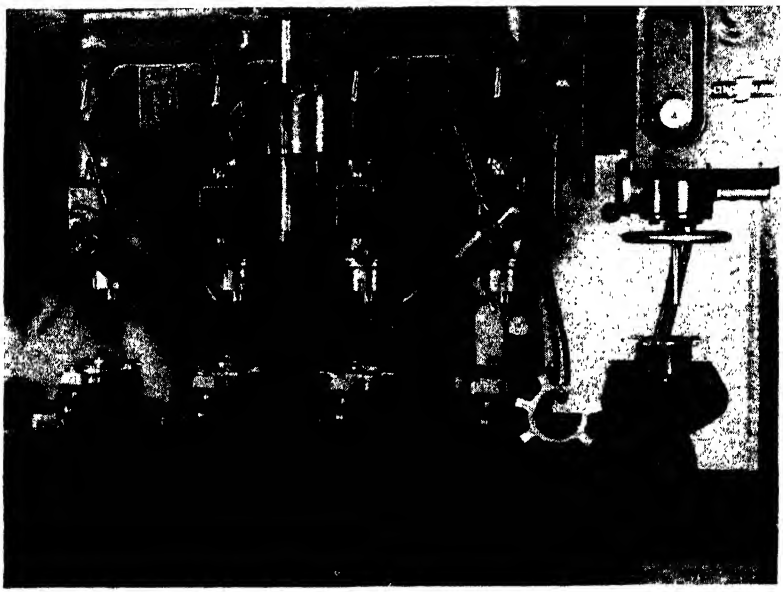


Fig. 44.—Profiling the outsides of four locking plates that hold rod pins in place in a seven-cylinder radial airplane engine.

With the four plates clamped in their fixtures, the whole milling head is lowered to bring the follower in contact with the master form and the cutters to the work. With the machine in operation, the table is fed automatically in both directions, keeping the follower in contact with the master form and following entirely around it. This completes four pieces at once.

An alternate method would be to mill a stack of these plates with form cutters and an indexing fixture. This would require special spacing for the wide gap. An alternate method would be to broach them, probably with an indexing fixture. The profiler has the advantage of using simple holding fixtures and standard milling cutters. These help to offset the extra cost of

the profiler over the regular milling machine and the cost of the broaching machine and its cutters special.

The profiler shown finished an average of eight or nine pieces per hour, floor-to-floor time.

An adaptation of the profiling idea is shown in Fig. 45, where a small motor carrying a milling cutter on the end of the spindle is used to trim the inside of airplane cowling segments to the desired radius.

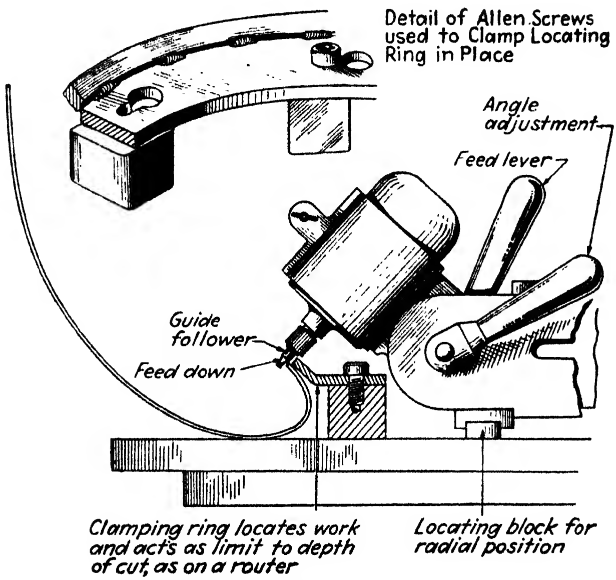


FIG. 45.—Motor-driven profiler for trimming airplane cowlings.

This little motor-driven profiler swings on an arm as shown and so cuts a true circle as it moves. The details of its construction and operation are seen in the illustration. The cowl ring is clamped in place by the plate and hollow-head setscrews shown above, while the other view shows the guide in place over the work and the profiling cutter and the guide almost in contact with the work.

The feed lever moves the routing cutter into the work until the follower contacts the guide plate. Then the profiling head is swung around by the arm and trims the entire circle of cowling. This is a very simple but effective method of profiling.

Profiling by Routing.—One popular form of profiling used largely in shaping one or more sheets of metal, plastics, or other material, is known as routing. This has been developed in the

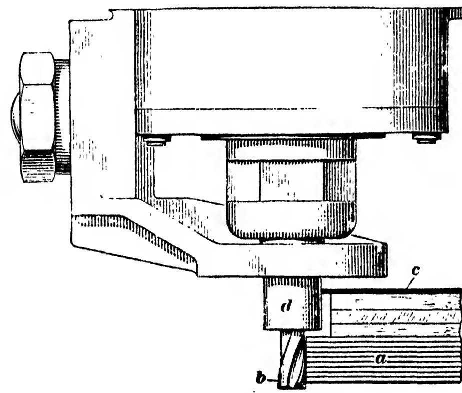


FIG. 45*a*.—How routing cutters are used to profile several sheets at one time.

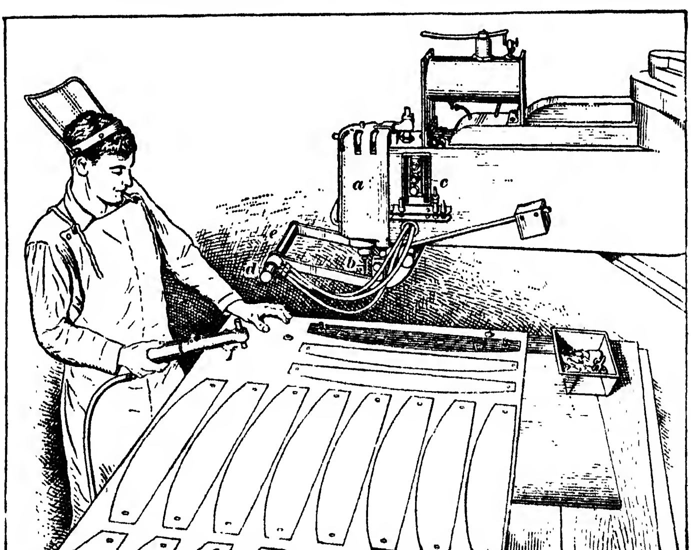


FIG. 45*b*.—How patterns are laid out on large sheets before routing.

airplane shops for cutting aluminum and duraluminum sheets for parts of planes. Some of these parts are very large.

In this work the former is usually a steel plate clamped on top of the sheets to be cut as in Fig. 45*a*. This shows nine

sheets of metal at *a*, the routing or profiling cutter *b*, and the guide plate or pattern *c* mounted on a plywood base. The thickness of this base gives room for the guide roller *d* above the sheets being cut. The plates *a* rest on plywood sheets that permit the point of the cutter to clear the lower sheet.

The patterns or forms consist of a steel plate *c* and its plywood support to which the plate is screwed. These patterns are laid

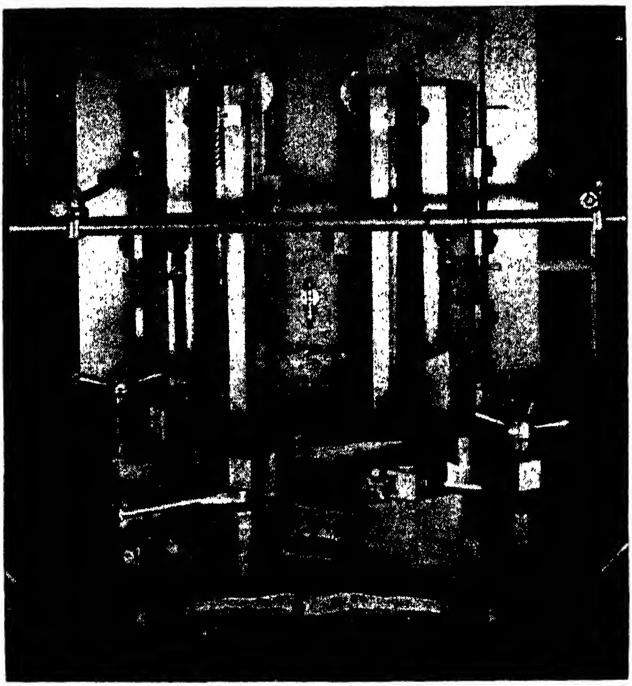


FIG. 46.—Broaching the end supporting surfaces of a cross member.

on a stack of sheets, usually 48 by 144 in. as in Fig. 45*b*, the average metal stock measuring $\frac{7}{16}$ in. The sheets are drilled for the screws that later hold them to the base.

Profiling by Broaching.—Profiling by the broaching method is rapid and economical when the quantity of work warrants the cost of the machines and the broaches necessary for the job. Several examples of broaching are shown in Figs. 46 to 48. As will be seen, special cutters and holding fixtures are required for each job, as is true in form milling. The broaches are a series of teeth, each a little higher than the preceding one, so that each

cuts a given amount of metal as it passes over the work. The length of the broach and the stroke of the machine depend on the amount of metal to be removed. In some cases it is necessary to have more than one broach so as to divide the work up among a sufficient number of teeth.

A comparatively simple job is seen in Fig. 46 where two flat surfaces are cut at the ends of the cross member shown. The

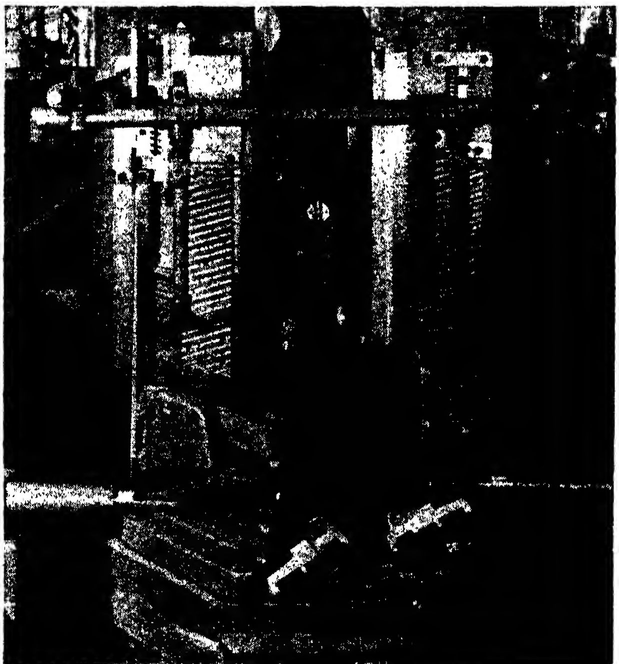


FIG. 47.—Broaching a trigger housing for a military rifle.

illustrations show how the work is held in suitable clamps and also the location of the two broaches so as to give the proper relation between the surfaces. It is essential that the work be clamped rigidly during the broaching operation.

Figure 47 shows the trigger housing of a rifle, both before and after broaching the sides and ends. This is hard material, S.A.E. 4150 steel of 179 Brinell, and the broaches remove $\frac{1}{16}$ in. of stock. The broaches are high-speed steel of the 18-4-1 type which run 34 to 36 ft. per minute. The roughing chip per tooth

is 0.0015 in. and the finishing chip 0.001 in. per tooth. The tolerance is 0.000 to 0.003 in.

The first operation broaches the right side and rear of the piece; the second operation broaches the front and left side. The working cycle is to broach with the left ram, swivel the table, broach with the right ram, then swivel the table back to the starting position. The work is removed and loaded from the

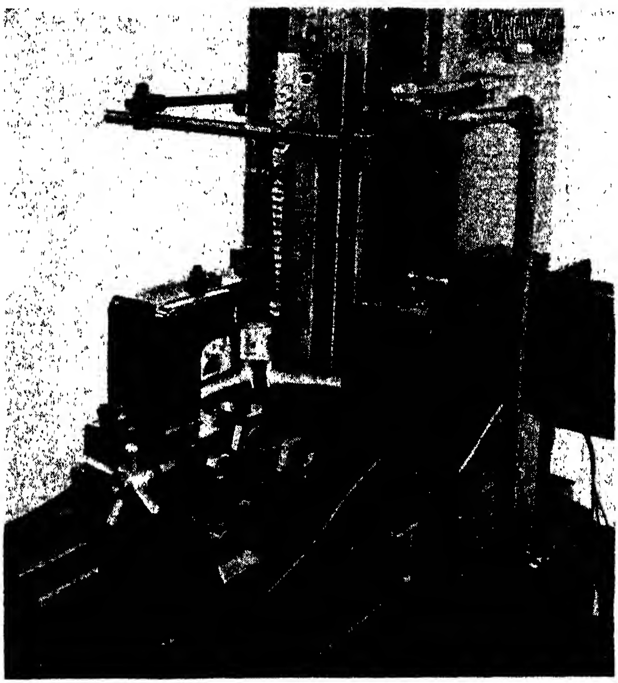


FIG. 48.—Broaching splines between arms of three-bladed propeller hub.

fixtures while the ram on that side is returning to the top of its stroke and the swiveling table is in the clear position. This combination secures an output of 133 pieces per hour.

In Fig. 48 splines are being broached between the arms of the hub of a three-bladed airplane propeller. The holding fixture moves back after each operation to permit the hub to be turned to a new position. The hub is locked in position by the screw at the end of the arm opposite the broach.

A Rotary Broaching Job.—Instead of the usual method of using a straight broach pulled through the work, the Allis-Chalmers

Co. found the rotary broaching method shown in Fig. 49 better for their work. This is broaching the opening on the inner ends of turbine blades by which they are fastened to the rotors in the tubine. The shape of the opening is shown clearly at *A* where a blade is in position ready for broaching.

The broach itself is seen at *B*, mounted on heavy supports bolted to the rotating chuck or faceplate of a machine of the lathe

Fig. 49.—Using a rotary broach for turbine-blade fastenings.

type. As shown, the clamp *C* is raised to give a better view of the work. When the piece is properly clamped, the machine is started and the broach goes through the opening at the end of the blade, finishing it to its proper dimensions. The machine then stops with the broach in the position shown until the finished blade is removed and a new one put in its place.

By broaching these blade ends in this way, they are cut on the same arc as the rotor on which they are fastened and give a full bearing. This would not be the case if they were cut with a straight broach.

Broaching Replaces Milling.—Either broaching or milling can frequently be used on the same job. An example of this is seen in Fig. 50, where two broaches are used in a Morton keyseater to cut slots in the ends of a casting. The casting is held on a hinged plate that is controlled by the toggle shown. As the broach starts to cut, the work is fed to the broach by the toggle. When the slots are cut to depth, the fixture is lowered, the

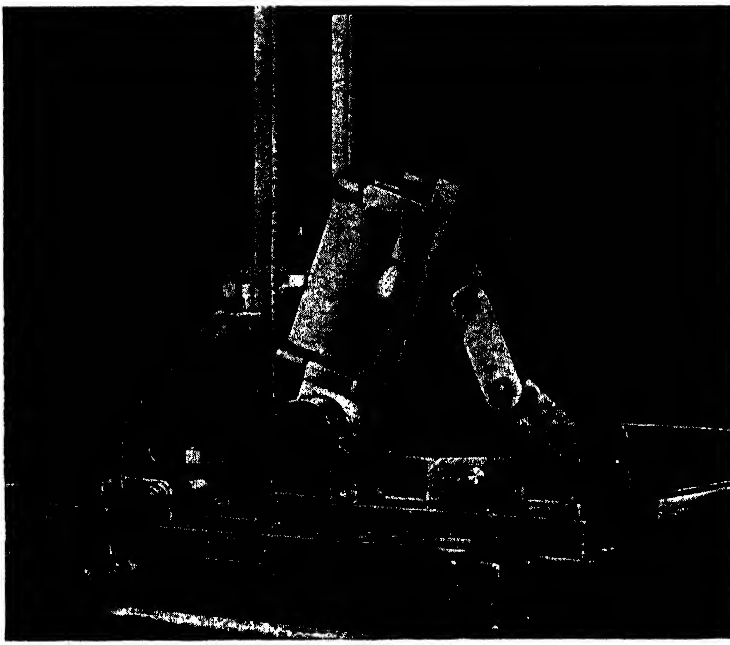


FIG. 50.—Using a Morton keyseater to cut slots in the end of a casting.

work changed end for end, and two slots are cut in the other end. This operation was originally done on a milling machine, but this handles the work more rapidly.

The Continental Motor shop also utilized a number of drilling machines for milling operations as seen in Figs. 51 and 52. The first shows the fixture used in holding the piston for milling the valve clearance spaces in the head. The open end of the skirt fits over the guide shown while the piston is located by the pin through the fixture and the piston pinholes in the work. The milling cutter that cuts the recess is driven by the drilling machine spindle and is guided by the bushing in the fixture. Figure 52

shows the piston in position for milling one clearance. The work is then indexed to the other position for the second operation.

Milling on a Boring Machine.—Three uses of the horizontal boring machine for milling are seen in Figs. 53 to 55. In the first, a locomotive cylinder bushing is shown mounted vertically on a rotary table while the steam ports are being milled. After the milling cutter has been started in one corner of the port, the circular feed of the table is thrown in and the bottom half of the

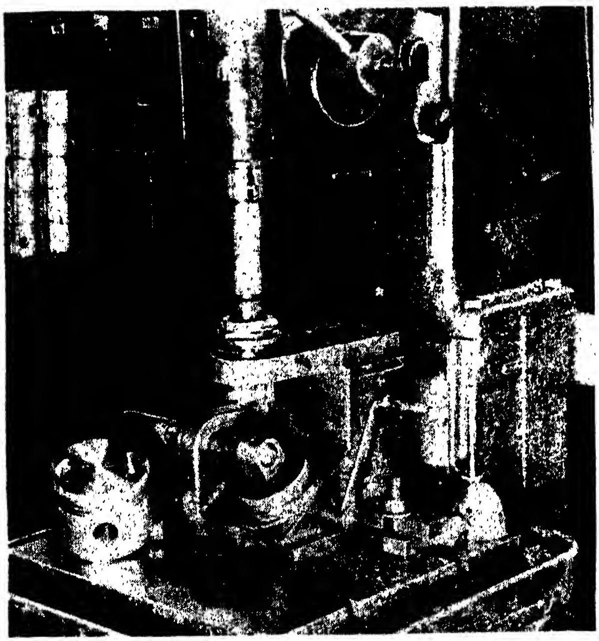


FIG. 51.—Fixture for holding a piston during the milling of the valve clearance spaces in the head.

slot is milled, as seen at the left where the cutter is at work. When the port is of the right length, the spindle is raised and the rest of the metal is milled out to make the ports as shown at the right.

Although this job might be done under almost any vertical-spindle machine, the horizontal table makes it much easier to handle. It also avoids a bad overhang as might be present if the valve bushing were in a horizontal position.

Such a job could be done in the engine lathe in an emergency by mounting a portable milling head on the lathe carriage. Or

it could be done by drilling holes at each end of the port openings and cutting out the piece with a lathe tool. This should be done only as a last resort.

Both Figs. 54 and 55 show jobs that would be difficult to hold in a lathe for facing the ends. In these cases the facing is being done by milling instead of turning, but it might have been done with a sweep tool as in the other cases. In Fig. 54 the cutter is large enough in diameter to mill the whole surface in one pass

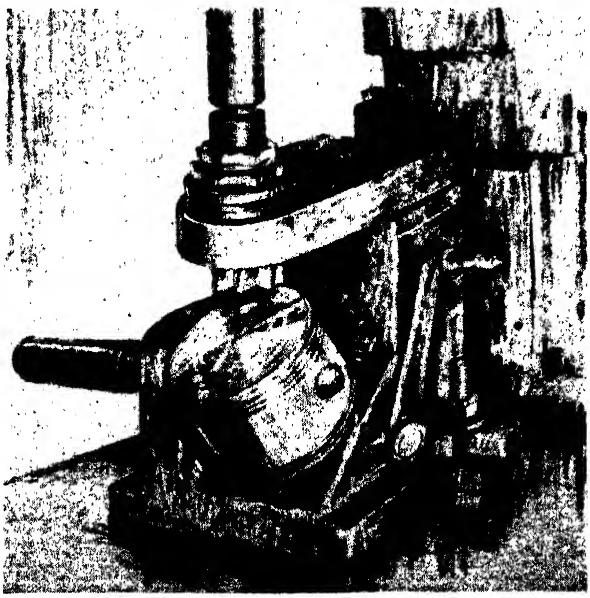


Fig. 52.—Piston in place in the fixture under the milling cutter.

across the end. In the other, it was better to use a small cutter and vary its height until it covered the entire surface. This is a case where a sweep cutter might have saved time over the milling method.

Gear Cutting on a Horizontal Boring Machine.—As with the engine lathe the horizontal boring machine can be used for a variety of jobs besides those for which it was originally designed. Following are three examples where these machines were used for cutting large spur gears when no gear cutter of sufficient capacity was available. We are indebted to the Lucas Machine Tool Co. for the illustrations and data.

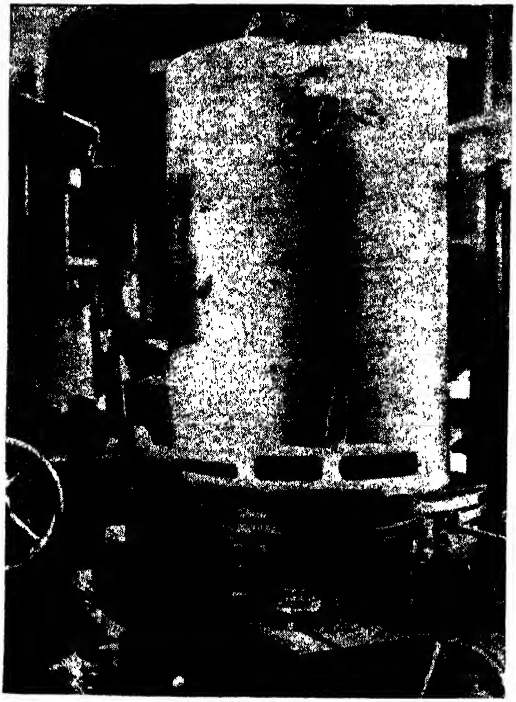


FIG. 53.—Milling steam ports in a locomotive cylinder liner.

FIG. 54.—Milling the flanges of crooked locomotive steam pipes.

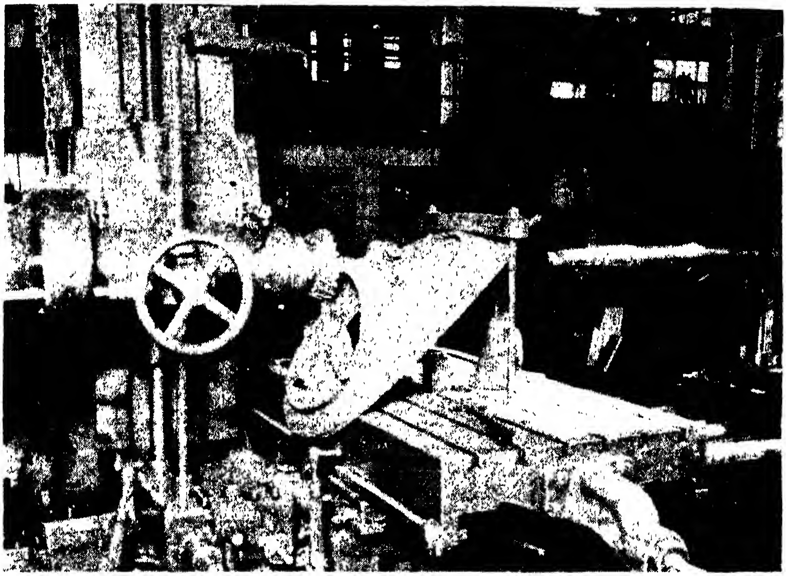


FIG. 55.—Milling an angular face on an awkward casting.

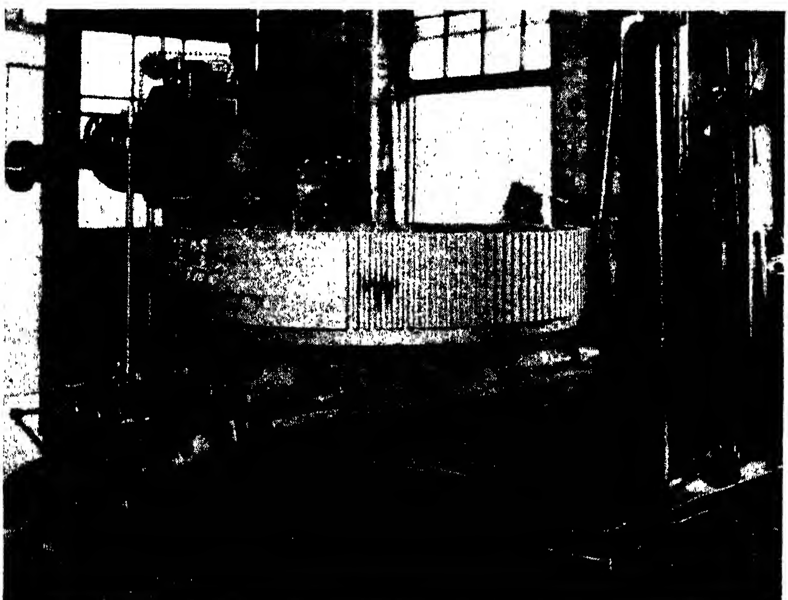


FIG. 56.—Using a special gear-cutting head on a Lucas horizontal boring machine.

In Fig. 56 a special gear-cutting head has been made for the machine. This is attached to and driven by the spindle head.

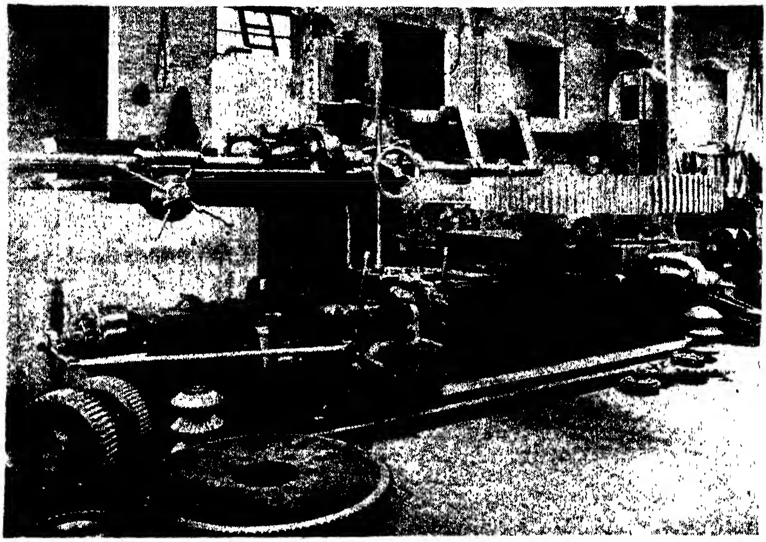


Fig. 57.—A boring-machine setup to cut a variety of gears.

Fig. 58.—Cutting the "bull" or main gear for a dredging machine on a Lucas boring machine.

The milling cutter is at right angles to the spindle and is driven through gearing inside the special head. This and the special indexing table which is mounted on top of the regular table of the machine indicate that this particular shop used the machine for

cutting gears as well as for boring as part of its regular work. Here the work is fed into the cutter to proper depth by moving the carriage along the bed while the cutter is fed down across the face of the gear by the regular elevating mechanism on the spindle head. The gear is indexed by the worm-actuated table through the index plate at the corner. The number of holes in

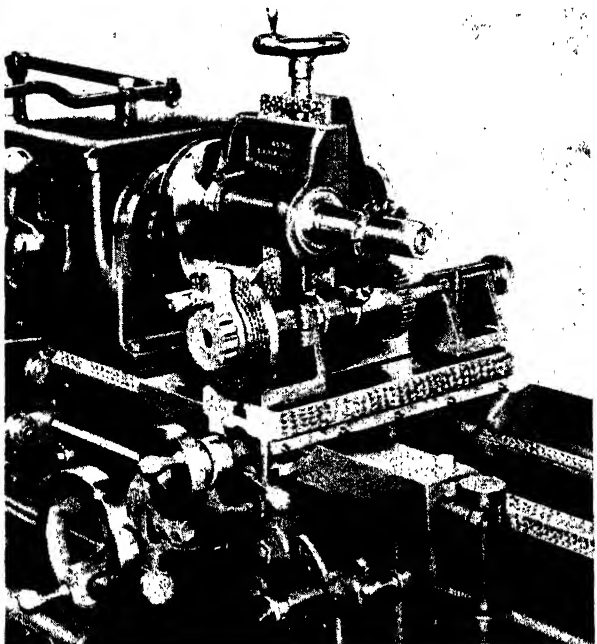


FIG. 59.—Globe gear-cutting attachment used on an engine lathe.

this plate indicates that the machine was used for a variety of gears.

Another Lucas machine that was used for cutting a variety of gears is seen in Fig. 57. Here the overarm connection between the spindle head and the outboard support is shown in place, and the cutter arbor is supported between bearings as close to the cutter as possible and still clear the gear blank being cut. The cutter is fed down through the cut by moving the head and the supporting arm in the outboard support. The work shown on the floor indicates that this machine is used to cut sprockets as well

as gears. The bevel gears indicate that these were cut on the same machine. Special holding fixtures would be necessary for this work, but the indexing would be done by the same table. For a maintenance shop with a variety of work, including gears, such a machine will be found most useful.

A most unusual job of gear cutting to be done on a machine of this type is seen in Fig. 58. This is the bull or main gear for a dredging machine and has a pitch diameter of 14 ft. 8 in. It is mounted on a 16-in. shaft and has 192 teeth of $2\frac{3}{4}$-in. pitch with a 15-in. face. The gear is of cast steel. The size of the gear

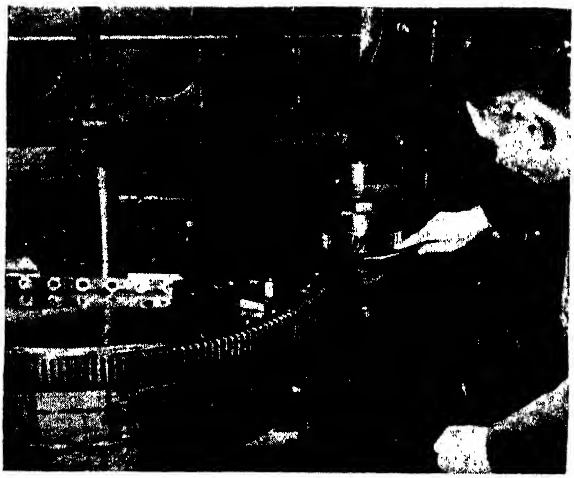


FIG. 60.—Using a boring mill as a gear shaving machine.

dwarfs the boring machine itself, but the large size of the cutter used gives some idea of the work it is doing. As can be seen, the first cuts are being taken. The indexing base that supports the gear is fed in for the desired depth of cut. Such a gear would require a very large gear-cutting machine which would stand idle most of the time in such a shop. It is the ability to utilize machine equipment with the possibilities of a wide range of operations that distinguish the all-round mechanic from the operator who is familiar with only one or two different types of machine tools.

Gear Cutting in the Lathe.—Many mechanics in small shops have built milling attachments for engine lathes and have used

them for a large variety of work. Although no one advocates their use in place of a regular machine, attachments do make possible the handling of many kinds of work that could not be done otherwise.

To avoid the necessity of designing and building such an attachment, there are a few of them available to those in need of them. One of these, made by the Globe Products Mfg. Co.,

FIG. 61.—Armstrong-Blum hydraulic hack saw.

Los Angeles, Calif., is illustrated in Fig. 59, shown mounted on the carriage of a 12-in. Sebastian lathe.

The milling head fits the ways of the lathe, and the spindle is driven from the lathe spindle by two V belts. Work is held between centers mounted on the saddle in place of the cross slide. This work-holding unit supplies work centers and an indexing plate or dividing head. As shown, the attachment is being used to cut a spur gear, the proper spacing being secured by the dividing head. A good mechanic can flute taps and reamers and do a variety of milling on such a device.

Shaving Gears on a Boring Mill.—Shaving gear teeth by the rotary cutter method was done on a vertical boring mill at the Pontiac Motors Division of General Motors Corp. in some of their work on the Bofors gun, as shown in Fig. 60. When this method was devised, no shaving machine could be secured for two years owing to the great demand caused by the war effort. So the elevating arc for the gun was fastened to the table of the boring mill, and the cutter was mounted on a special fixture, as shown, and bolted to the toolhead of the machine.

In the illustration, the rotary cutter is raised out of the work to show how it is set at the right angle to get the shaving action between the teeth of the cutter and the work. As the boring mill table revolves, it carries the work past the cutter which is free to turn on its spindle. The shaving done by this method was perfectly satisfactory in every way.

Hydraulic Hack Saw.—A departure from the usual design of power hack saw is found in the hydraulic saw built by the Armstrong-Blum Mfg. Co. and shown in Fig. 61. The saw is held in a sort of crosshead supported in the upper frame of the saw and is driven by a crank, through a chain mechanism coming down from the top of the frame. The hydraulic feature is confined to the feed.

The weight of the upper housing is used to secure the pressure necessary for feeding the blade into the work. As this upper housing weighs 2,000 lb., the feed must be controlled by hydraulic mechanisms to give the desired pressure on the blade. The round housings act as pistons, and the weight of the housing develops a pressure of about 100 lb. per square inch. Suitable valve controls make it possible to vary the pressure on the blade to conform to the resistance of the work to the cut. This work resistance varies with the hardness or toughness of the material, condition of the blade, breadth of the cut, and the depth of feed.

The accompanying table gives the cutting speeds suggested by the makers.

Consolidated Cold Saw.—The Newton cold saw (Fig. 62), made by the Consolidated Machine Tool Corp., also has hydraulic feeding mechanism which controls movement in both directions so that the saw teeth cannot draw the work toward the blade itself. This saw also makes its cut *up* instead of down as was

MARVEL NO. 18 HYDRAULIC HACK SAW

Speeds

Classification of steel	Carbon range of steel	Speed, strokes per minute
Carbon steels, S.A.E. 1000 series	Up to 0.50 0.50–0.60 0.60–0.75 0.75–0.90	160 125 100 80
Free-cutting steels, S.A.E. 1100 and 1300 series	....	165
Manganese steels, S.A.E. T1300 series	Up to 0.40 0.40–0.50	85 75
Nickel steels, S.A.E. 2300 series	Up to 0.50	160
Nickel—chromium steels, S.A.E. 3100, 3200, 3300, and 3400 series	Up to 0.30 0.30–0.40 0.40–0.50	160 130 100
Molybdenum steels, S.A.E. 4100 series	Up to 0.40 0.40–0.50	160 130
Chromium steels, S.A.E. 5100 and 5200 series	Up to 0.20 0.20–0.40 0.40–0.50 0.50–1.00	160 130 100 80
Chromium-vanadium steels, S.A.E. 6100 series	Up to 0.35 0.35–0.40 0.40–0.50	160 130 100
Silicon-manganese steels, S.A.E. 9200 series	0.50 0.60	100 80

Feed Settings

Maximum width of work, inches.....	3	6	9	12	15	18
Variable feed (pressure), pounds.....	600	425	275	200	175	150
Positive feed (max. limit), inches.....	24	18	14	10	8	6

formerly the practice. This is to prevent the lifting of the saw carriage that might result from varying pressures on the work as the cut proceeds. With the upward cut, the carriage is seated on the ways at all times. As a result, it is claimed that saws can cut much faster and also have longer life owing to more uniform action of the teeth in the work.

FIG. 62.—A cold saw that cuts "up" in order to hold the saw carriage down on the bed.

By ensuring a uniform rate of feed with the hydraulic control in both directions and the positive action of the cutting teeth on the work, it is possible to increase the chip per tooth and secure higher production. A stock machine is cited as cutting a 9-in. round bar of S.A.E. 1040 steel in 3½ min.; a 5¼-in. bar of 0.60–0.70 carbon steel in 2⅓ min.; and a chrome-vanadium bar of the same size in slightly less time.

A Large Rotary Planer or Miller.—Another very large machine tool is seen in Fig. 63. This is usually called a "rotary planer,"

but it is in reality a type of milling machine, one of the first to be used in large and heavy work. Here, too, the toolhead moves along the bed, as with the armor-plate planer, although this is not always done in rotary planer design. In this case, the ways on which the cutter head travels are protected by sectional metal covers that telescope over each other as the head moves along the

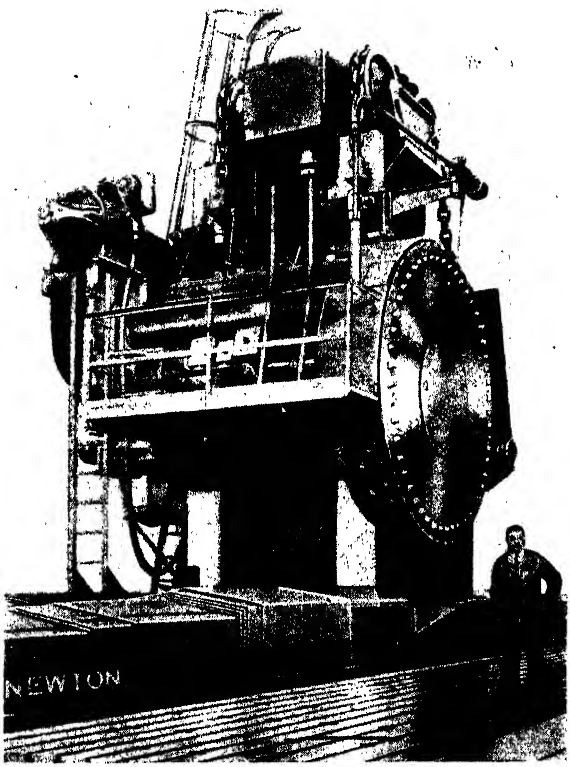


FIG. 63.—Large rotary planer or milling machine.

bed. On smaller rotary planers the table usually moves the work past the stationary cutter head.

The large milling cutter is driven from the motor at the upper left-hand corner which drives a worm. There is another reduction gear before the power reaches the cutter head itself. Needless to say, this type of machine is used only in milling large surfaces on huge castings bolted to the stationary bed at the

right. This particular machine is 80 ft. long and weighs more than 600,000 lb. It is used also as a cold saw by bolting a special saw arbor or carrier to the cutter head, as shown in Fig. 64.

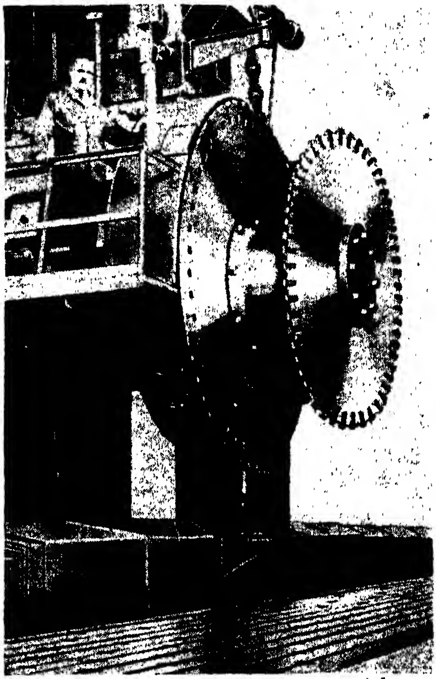


FIG. 64.—The same machine with a circular saw at the end of the spindle.

These are both special tools built by the Consolidated Machine Tool Corp., Rochester, N.Y., one of the few builders of very large machine tools in this country.

CHAPTER VII

PLANING, SLOTTING, SHAPING, AND MACHINE FORGING

Planing, shaping, and slotting are all standard operations that have been in use for many years. They are primarily for producing flat or plane surfaces by moving either the tool over or past the work, or the work under or past the tool. Although this operation is also done by milling, grinding, and broaching, there are many kinds of work in which the older machines still have first place. Both milling and broaching require special cutting tools. The use of grinding wheels prevents reaching into corners and confined places that can be machined by tools in the planer, shaper, or slotter. So, although they are not tools for mass production, except in some of their special forms such as the gear shaper, these machines have a very important place in the average machine shop and in the production of some of our most important products. This is particularly true in the building of large machinery of any kind, such as engines for steamships, locomotives, steam shovels, tractors, or sugar machinery.

PLANING

Several types of these machines were illustrated in earlier chapters, some of them shown doing work of various kinds. For this reason, this chapter will be confined to a few illustrations of more or less unusual jobs. One of these is the planing of the special contour on the large impeller for a rotary pump, shown in Fig. 1. Here the planer hand must follow the desired contour of the impeller with great accuracy in order to give the desired efficiency of the pump in operation. The work has to be turned at intervals to allow the planer tools to reach the different portions of each lobe. This job would be very difficult to do in any other way and requires a man with extensive experience in handling large planers on work of this kind.

Another planer job, which puts it more into the production class of machine tool, is seen in Fig. 2 where two tables are used

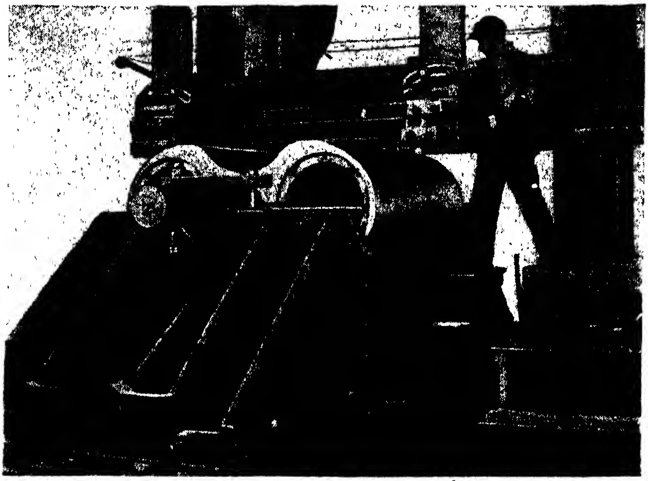


FIG. 1.—Planing formed lobes of a large impeller for a rotary pump.

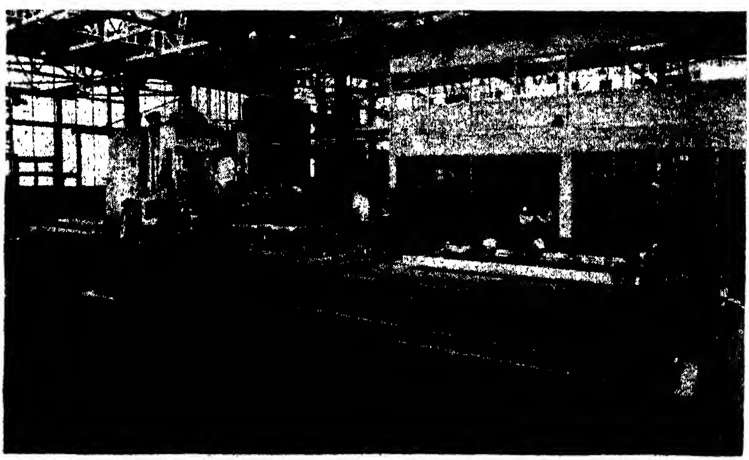


FIG. 2.—Long-bed Cincinnati planer with a divided table.

on an extra-long bed, provided with two planer tables for carrying the work.

Planer with Divided Table.—There are many shop jobs where the time required for setting up the work takes a large proportion

of the total time of the operation. Where this keeps the machine idle during this setting-up time, the machine is not giving its maximum production. To avoid this, it is possible to plan in many cases for setting up the work in fixtures and simply stopping the machine long enough to change the fixtures.

In the case of planers this is sometimes done by having what may be called "false" tables which are transferred to the planer table after the work has been set up. Figure 2 shows another method. Here the planer has a divided table, only one portion being in use at a time. As shown, the left-hand portion is at work while another piece of work is being set up on the right-hand half. When the work is completed, the left-hand portion will be run out of the way and the other half of the table connected to the driving mechanism beneath. This method, according to the Ohio Steel Foundry Co. in whose shop this picture was made, makes two planers do the work normally done on three.

An Unusual Planer.—The distinguishing feature about the usual planer is that the work is fastened to a table which moves under the stationary cutting tools. It is the shaper in which the tool moves over the stationary work. In the Betts machine, shown in Fig. 3, the work is on a stationary table in the center and the tools move over it. This is known both as an armor-plate planer and a pit planer, the latter name being used because the work table is in a pit between the two ways on which the uprights move over the work. The size of the planer can be seen by comparing it with that of the operator at the right end of the crossrail. The height is 18 ft., the width 42 ft., and the length 76 ft. The weight without motors is 650,000 lb. Both the dimensions and the weight are approximate.

The right-hand head has an angle bar, similar to the taper attachment on the back of an engine lathe, to control the movement of the tool in that head. In this way one edge of the armor plate can be planed to the angle desired in making joint with the next plate. Both sides of the traveling head are driven by screws, one of which is shown at the left. In this kind of work it is considered better to move the heavy planer housings than the armor plate being planed. Oddly enough this same construction is used on the newer types of milling machines found in airplane factories for machining the long wing spars from alumi-

num billets. Here, however, it is not the weight of the pieces being machined that influences the moving of the cutting head, but the extreme length of the work being done. These special-type milling machines are long and narrow but of comparatively light weight. With usual planer construction, the beds would have to be twice the length of the moving work table and would take up too much space in the shop.

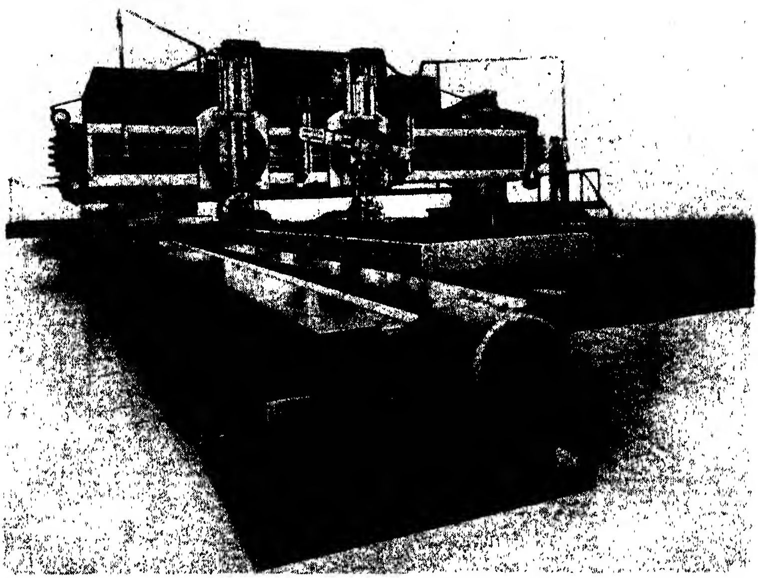


FIG. 3.—Large Betts planer for armor plate. Here the housing, crossrail, and toolhead travel over the work.

An Unusual Planer Job.—An unusual and interesting job on a Cincinnati planer is shown in Fig. 4. The work is the stern-tube bearing for a main propeller shaft in which the slots for the bearing strips are being planed. The different slot positions are reached by swinging the toolhead to the various positions marked on the semicircular plate mounted on the tool slide.

As shown, the tool in working position is roughing out the bottom of each slot. The width of the slot is secured by feeding the tool on the crossrail. When the slot has been cut to depth, the toolholder is turned 180 deg. to bring the tools in the other end of the toolholder into cutting position.

These tools are set at the proper angle to make a dove-tail to hold the rubber-faced bronze bearing strip that goes in each slot. The angular cut is secured by feeding the tools sideways into the slots that have been planed, until the desired dovetail has been secured. The same kind of job could have been done

FIG. 4.—Planing slots for bearing strips for a stern-tube bearing of a large vessel.

on a planer-type milling machine using a plain end mill and then an angular milling cutter to make the dovetails on the side of the slot. But this would have required special cutters. Although these might pay if a sufficient quantity was to be made, the simplicity of the planer tooling makes it highly desirable for work of this kind.

SLOTTING

Utilizing an Old Slotter on War Work.—The old slotter seen in Fig. 5 was salvaged for a special war job by L. W. Coale,

factory manager of the Western-Austin Co. The job was the firing jack of 155 mm howitzer carriages. After renewing the bearings and scraping the ways of the old machine, a special fixture was made to hold the work, a piece being shown on the floor beside the machine. Four special tool carriers were also

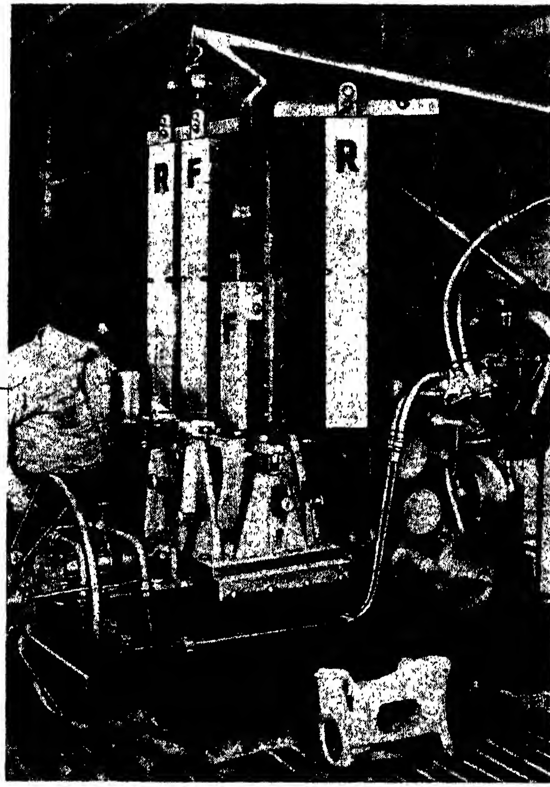


FIG. 5.—Using an old slotter on a special war job.

designed and built for the work. The two marked with the big *R* are for roughing the casting, and those marked *F* are for the finishing cuts. One of the *F* bars is seen in place in the ram of the slotter.

These bars are guided in a bronze-lined bearing made after cutting a hole in the base of the machine. This guide was necessary in order to secure the desired accuracy of plus or minus 0.003 in. in the machined portions. The bars are handled

by the jib crane seen behind the machine, and the bars are stored on the rails at each side of the column when not in use.

A hydraulic ram is used to move the work-holding fixture away from the cutting tool on the return stroke of the ram and to replace it in position for the cutting stroke. This is done by a cam welded to the main driving gear of the slotter. This cam

Fig. 6.—Slotting a stack of plates on a Pratt and Whitney vertical shaper.

controls a valve so that the fixture will move $\frac{3}{64}$ in. at the proper time. This relieving movement protects the cutting edges of the tools on the return stroke of the ram.

The tools were made of S.A.E. high-speed steel brazed to shanks of S.A.E. 3140 steel. The rake angles for the cutting edges were 3 to 5 deg., and the clearance angles were 8 deg.

Another slotting job is shown in Fig. 6 where a stack of steel plates are set up on the rotary table of a Pratt and Whitney toolroom vertical shaper, which is a precision slotting machine. With the rotary table set in the position shown, the stack of plates can be machined on all four sides by turning the table.

Cutting Large Gears on a Slotter.—An unusual type of floor boring mill is shown in Fig. 7. This was built by the Simmons Machine Tool Corp. for use by the Camden Forge Co. in making the rings on which the turrets of modern battleships turn. These rings incidentally, are forged in one piece and not welded, to avoid the possibility of breakage from the recoil of the guns. This boring mill will turn rings 36 ft. in diameter.

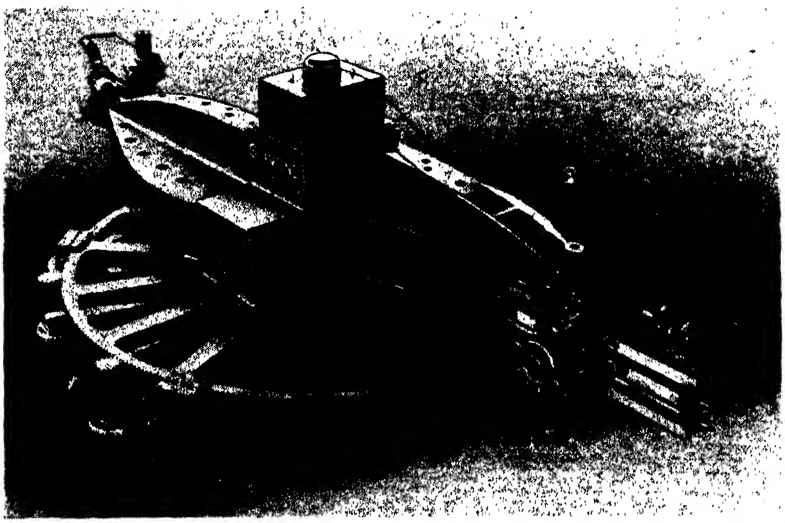


Fig. 7.—Unusual floor-type boring mill for machining turret rings for modern battleships.

As few shops have gear cutters that will handle gears of this size, 24 ft. in diameter, Samuel Koffsky, the chief engineer, devised a method by which the teeth could be cut on a Dill-type slotter which was available. After the gear blank was machined to the correct outside diameter and the sides faced, both the pitch diameter and the root diameter of the teeth were scribed on the machined surface, on one side of the rim. The teeth are then laid out roughly by the use of a templet and dividers, but they are accurate enough to allow ⅛ in. for finish.

The first operation was to remove the bulk of the material between the teeth with a radial drill set near the slotter. Figure 8 shows an outline of the tooth with the amount of metal removed by the different operations, as indicated under the illustration. Material from sections 2 and 3 was roughed out by the slotter.

The rough machining removed stock to the full depth of the tooth, but enough metal was left on the sides of the teeth for finish-machining to proper size and shape.

Precision indexing was done by the use of ground disks and a gage block. In theory, a number of identical disks equal to the number of teeth in the gear and properly placed around the gear will touch each other as in Fig. 11. In a straight rack the diameter of these disks will be exactly the same as the pitch of the gear teeth. For external gears, the diameter of the disks is smaller than the circular pitch; for internal gears, it is larger.

The approximate diameter of these disks is easily calculated. Add 0.001 in. to the calculated diameter and make five disks ½ in. thick, ground to this diameter. A ⅝-in. hole is drilled through the center to facilitate clamping the disks in place (Fig. 9). For ease in identifying the disks, they will be numbered from 1 to 5.

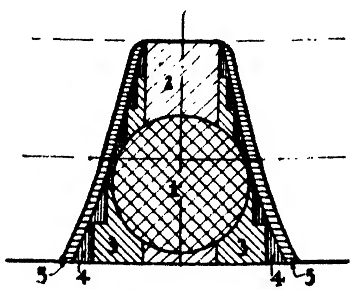


FIG. 8.—Outline of gear tooth showing the metal to be removed.

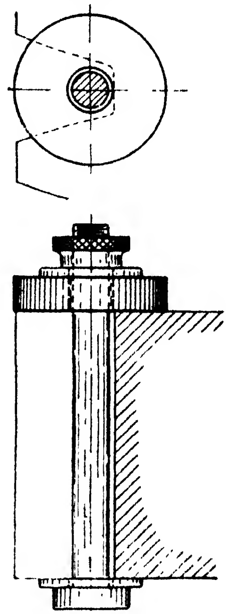


FIG. 9.—Disks clamped in place to check accuracy of the teeth.

Disk 1 is clamped on the gear rim so that the edge is tangent to the face circumference of the gear. Disk 2 is placed adjacent to and touching disk 1 and is likewise clamped in position tangent to the outer circumference of the gear. Disks 3, 4, and 5 are placed in like manner.

Disk 1 is not disturbed and remains as a locating point for the start of the indexing. Disk 2 is carefully removed and clamped in position adjacent to disk 5. Disk 3 is removed and placed

next to disk 2 in its new position. This procedure is continued, moving the four disks, 2 to 5, around the circumference of the gear until we approach disk 1, which was left in its original position.

Because the disks were ground 0.001 in. oversize, the last remaining space should be too small to accommodate a disk. A micrometer measurement is taken of this space, and the difference between this measurement and the diameter of the disks is noted. Dividing this difference by the number of teeth in the gear gives the amount that should be removed from the diameter of the disks. In grinding the disks to the new diameter, care should be exercised to leave them a fraction of a thousandth oversize.

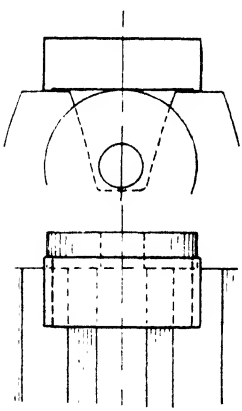


Fig. 10.—Special gage block used to position the disks against the outer surface of the gear.

Next, a second circuit of the disks around the rim of the gear can be made. This time a special gage block is used to position the disks against the outer circumference of the gear. This block is made as shown in Fig. 10. Its length is a fraction more than the tooth spacing and it has two small pads $\frac{1}{8}$ in. wide by $\frac{1}{64}$ in. thick at the ends of the side that is placed against the gear face. In operation, the block is placed with the small pads against the gear face, the top surface of the block projecting about $\frac{1}{8}$ in. above the rim. In clamping the disks, each one is placed in contact with this block and also with the adjacent disk.

As before, disk 1 is clamped in position and remains unmoved to serve as a point of reference, and the distance between the last disk applied and disk 1 is measured. This distance may now be somewhat too great, by, let us say, 0.030 in. No further grinding is necessary on the disks, but a small amount is removed from the two pads of the gage block, thus bringing the disks nearer the center of the gear. The amount necessary to be removed from the pads is approximately one-sixth the closing error, in this case 0.005 in. A third circuit of the disks should now show practically perfect spacing.

The next step is the finish cutting of the gear teeth, using the disks and the gage block in combination, for indexing the tooth

spacing. A milling cutter can be used for this operation, but a heavy-duty slotter with an in-feed attachment for the tool has been found most satisfactory. Accurate grinding of the form tools is most important, and the full profile should be removed at the finish with a fine feed.

The indexing is accomplished by setting up a dial indicator on a substantial immovable base, some distance away from the slotter, at least 90 deg. around the circumference of the gear. The five ground disks are clamped in position, side by side, with each disk set tangent to the gage block. The indicator is

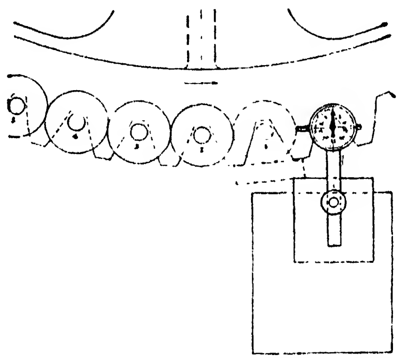


FIG. 11.—Actual indexing of gear was done with the aid of a dial indicator by bearing it against one of the special disks.

brought against disk 1 until it reads zero, as shown in Fig. 11. The first tooth is then finish cut. Disk 1 is removed and the gear rotated, closing up the space until the indicator reads zero against disk 2. While the second tooth is being cut, disk 1 is placed beyond disk 5. This procedure is continued until all the teeth have been finished.

The principal advantage of this method of indexing is that it eliminates the possibility of accumulating errors. Any error in an indicator reading on one setup is nullified at the next succeeding setup. With a reasonable amount of care, a rigid machine for cutting, and proper tooling, it becomes possible to cut large gears with tooth spacing deviating not more than one or two thousandths of an inch from the theoretical spacing.

SHAPING

Shaper Work.—Both large and small shops can use shapers on a wide variety of work, preferably where the length of the cut is

not long enough to use the full stroke of the ram. The main thing is to avoid spring movement in the work or tool from either the work's not being supported under the cut, or not being held

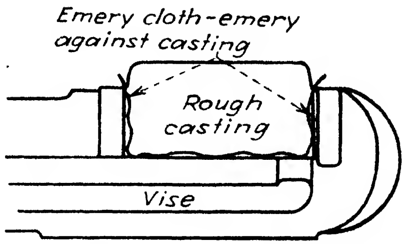


FIG. 12.—Using abrasive cloth to aid in the clamping of rough castings or forgings.

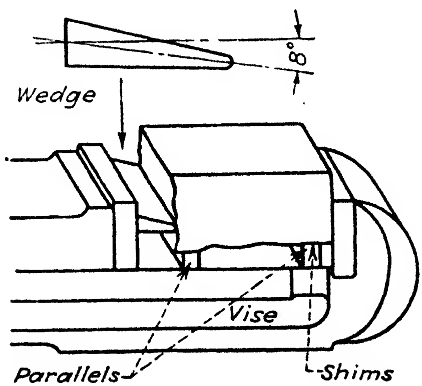


FIG. 13.—Using parallels, shims, and wedges to hold work in the vise.

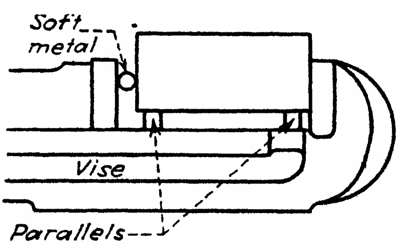


FIG. 14.—A soft-metal clamping rod or strip helps in holding work in a vise.

securely in the chuck or vise. The Cincinnati Shaper Co. offer valuable suggestions in Figs. 12 to 18. The illustrations are largely self-explanatory.

Care should be taken to see that all clamping surfaces are clean and free from nicks and burrs. Work should be tapped

with a soft hammer, babbitt or rawhide, to be sure that it is seated solidly in the vise. The true side of the work should be placed against the solid jaw of the vise. A small rod against the other side, as in Fig. 14, helps to hold work firmly. Although this shows a soft metal rod, even a steel rod is better than contact with the whole jaw. If castings or forgings are rough, abrasive

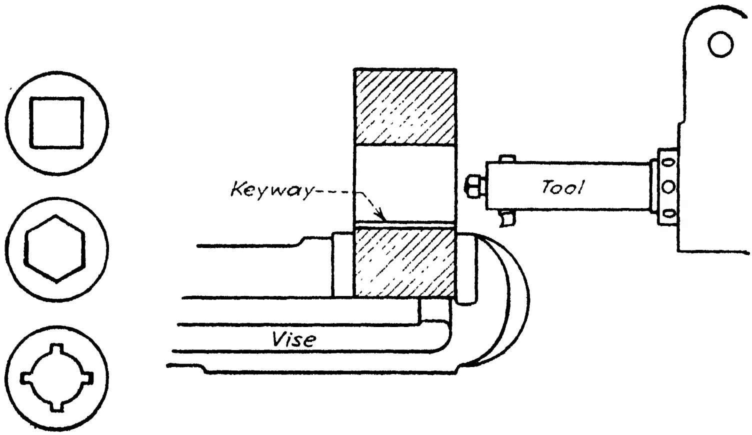


FIG. 15.—Shaping keyways or internal surfaces of various kinds.

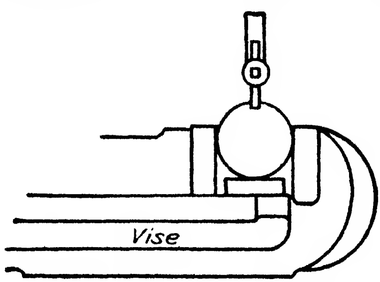


FIG. 16.—Cutting a keyway in a shaft held in a vise.

cloth should be used between the work and the vise, with the abrasive side against the work, as in Fig. 12.

Contouring, as in Fig. 19, requires care on the part of the operator. The desired outline is laid out in any way that seems best and should be followed carefully by adjusting the tool as it feeds across the work. This shows the outline prick-punched and scribed on the surface. In all cases the point or edge of the cutting tool should be set so that any spring will take it *out of the work* as shown at the right in Fig. 20.

Where the work or the tool has excessive over-hang, a sharp-pointed tool with a $\frac{1}{32}$-in. radius should be used. This will tend to eliminate chatter and give a smoother surface than if blunt tools are used. Clamping bolts should be as near the work as possible, with the clamps level. The supporting block should be kept at the other end of the clamp, away from the bolt.

Two ways of setting work level and parallel are shown in Figs. 21 and 22. The first uses a dial indicator in the tool post

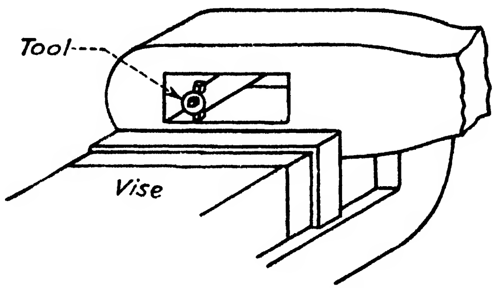


FIG. 17.—Shaping an internal opening in a connecting rod.

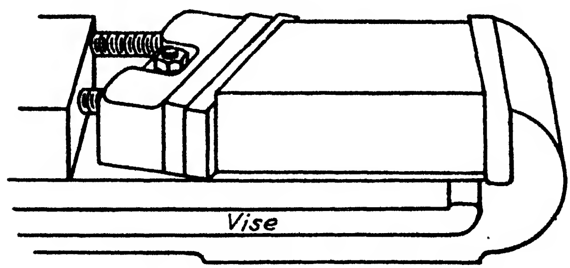


FIG. 18.—Vise with a swiveling jaw and two clamping screws.

of a shaper; the other shows how a surface gage can be used for the same work. Figure 23 shows the cutting of a Kennedy keyway in the bore of an eccentric. This type of keyway uses two square keys in corresponding keyways cut in the shaft. It is not commonly used but has its good points. It is easily made with the type of cutter shown.

Most of these principles apply equally well to planer work.

Some Unusual Jobs on the Gear Shaper.—Unless one is familiar with the work of the Fellows gear shaper, he does not appreciate the wide variety of irregular work that can be done on it. Although it is designed and used primarily for cutting gear teeth, some idea of the wide range of work to which it can be

applied can be seen from Figs. 24 to 27. In these illustrations the cutters shown in solid lines are used first while the second cutters machine the other side of the work to the desired shape.

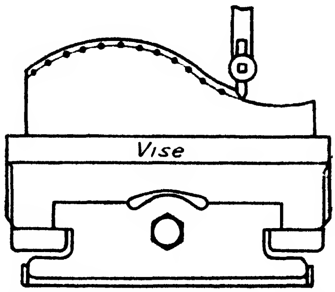


FIG. 19.—The following of a contour that has been prick-punched and outlined

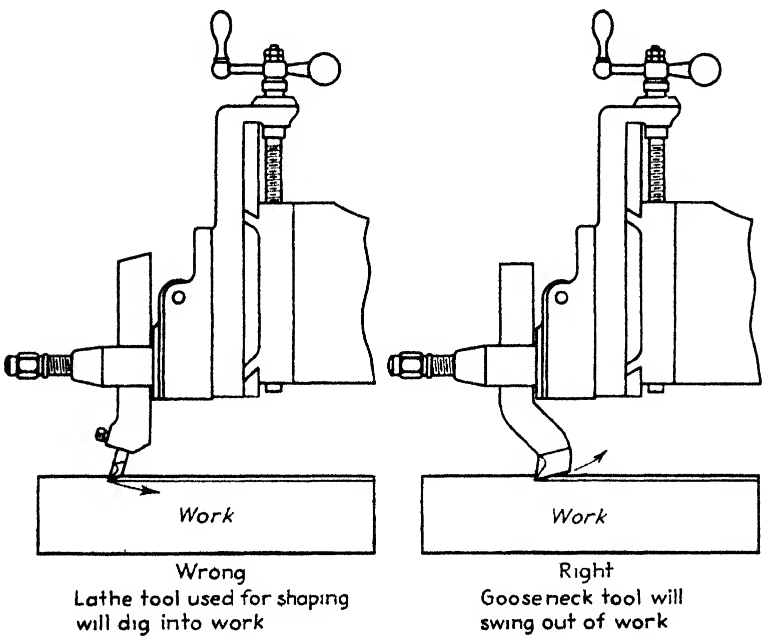


FIG. 20.—Right and wrong ways of setting tools for shaper or planer work.

The work pieces are in solid block. In Fig. 24 only one side of the piece is being machined. The cutter carries four outlines and so can be used until all are dull before being removed and sharpened. The same is true of both cutters in Figs 25 and 27.

In Fig. 26 the first cutter has three cutting edges, and the second carries five contours or outlines.

Both work and cutter revolve during the operation, and it can be readily seen how the contours or outlines of different

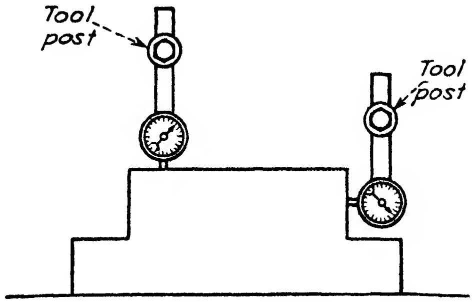


Fig. 21 Setting work level and parallel with dial indicators.

pieces are generated by this method. If these were very thin pieces, they would be made on a punch press. But, although thick metal pieces can be punched on heavy machines when they are small in relation to their thickness, the punch-press method

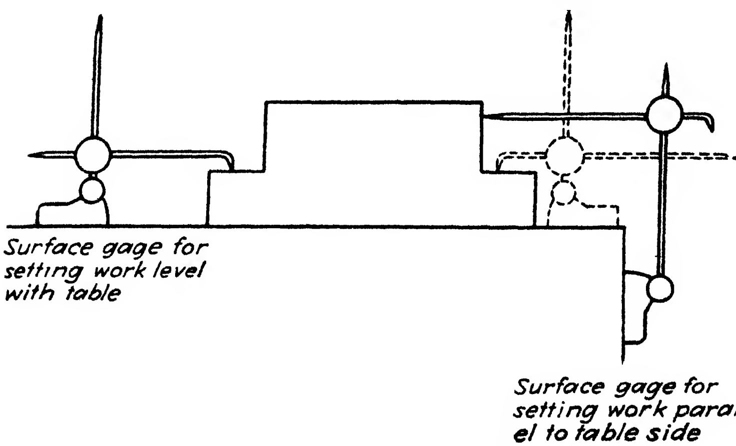


Fig. 22.—Using a surface gage in place of a dial indicator.

is no longer the best. By this method, the correct shape is secured with greater accuracy and at higher speeds than would seem possible to those not familiar with this method.

These are all parts of the firing mechanism of guns and similar small arms. Such parts were originally made on the milling

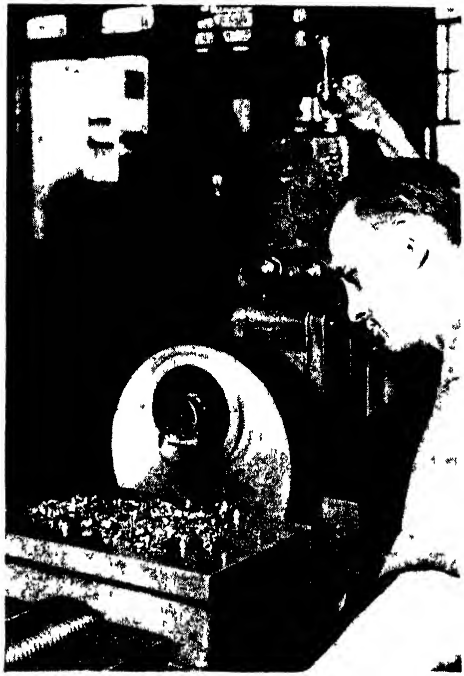


FIG. 23.—Cutting a Kennedy type of keyway with a special cutter

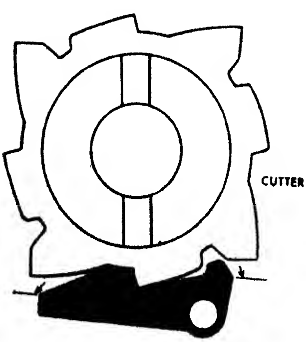


FIG. 24.—The cutter has four contours and can be used in any of the cutting surfaces.

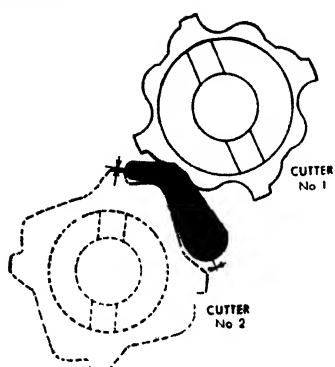


FIG. 25.—This job requires two cutters, but each has four cutting surfaces.

machine of the Lincoln type. Specially formed cutters were needed for milling as in this case although the cutters are entirely different in shape, the gear shaper cutters being less expensive to make and keep in cutting condition.

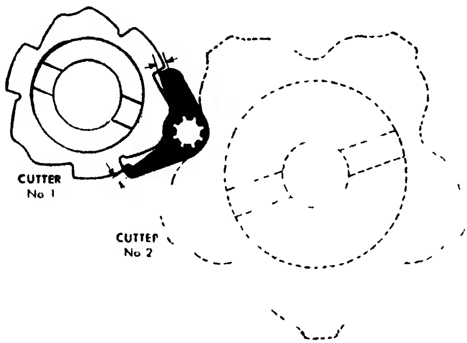


FIG. 26.—This job also needs two cutters. The small one has three work surfaces, the large one five.

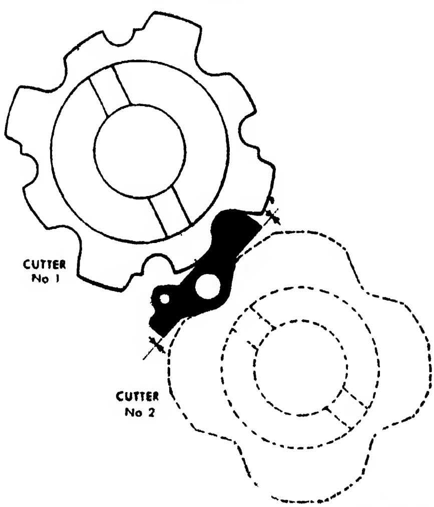


FIG. 27.—Each cutter in this pair has four working surfaces.

Shaping Seven Contours on One Piece.—The part shown at the right in Fig. 28 is for war production and is most unusual in having seven different contours on a single part. This is ideally laid out for a gear shaper job as no other machine could handle it in production fashion. The work requires very little description as the seven operations are clearly shown by the outline illus-

trations at the left of the piece itself. Begin with the gear at the top. This is a simple job for the gear shaper when the necessary recess is provided between the gear and the first cam, as shown. Then each operation can be followed by carefully studying the shapes and direction of movement of each cutter and the work it does.

It is interesting to note the transition from the full gear at the top to the last two disks, with one and two teeth, respectively.

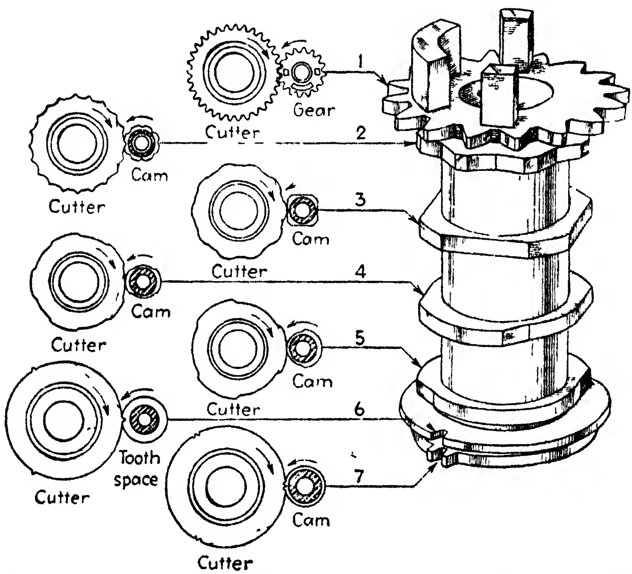


FIG. 28.—An unusual gear-shaping job in which seven different surfaces are produced.

A study of these various contours gives a good idea of the great variety of shapes that can be produced by this method. Cams 2, 3, 4, and 5 are all different; 3 is square except for the rounded corners. Without a machine of this type it would be necessary to make up the different gears and cams separately and fasten them together on a sleeve or barrel. Not only would this mean considerably more work, but it would necessitate extreme care in assembling them in exactly the proper position. This machine makes it possible for designers to use almost any shape they need without prohibitive cost of machining.

MACHINE FORGING

Forging by steady pressure rather than by blows from a falling weight or from a steam or air-driven hammer head is called "machine forging." Although much newer than the other methods, it has made a place for itself and has many interesting and economical applications The simplest example of this is the boltheader in which the end of the bar is heated, the bar

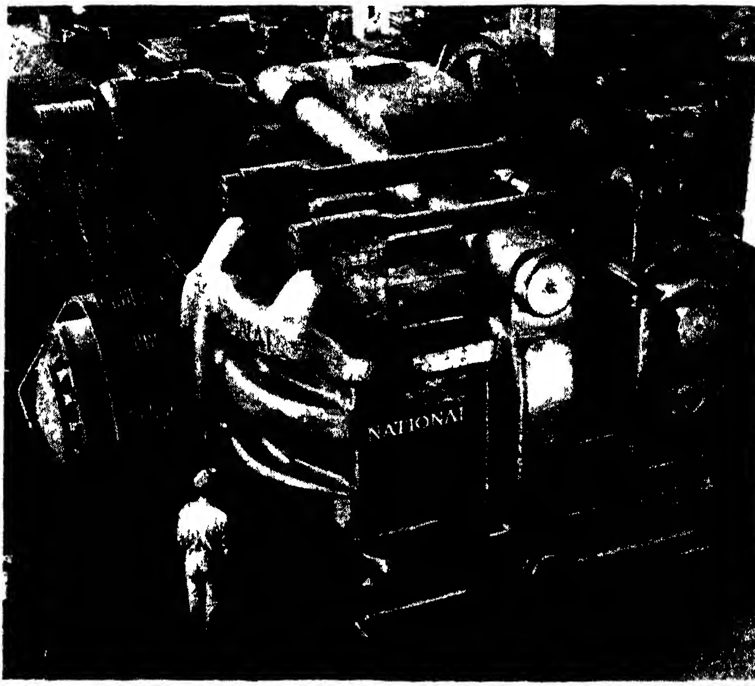


FIG. 29.—A large National forging machine weighing 500,000 lb.

clamped in suitable jaws, and the heated end forced into a die which gives it the desired shape.

This type of machine has been developed from the small bolt-header to the machine shown in Fig. 29, which handles bars 9 in. in diameter. The size can be judged by the man at the left. This machine makes 25 strokes per minute, requires a 250-hp. motor, and weighs 500,000 lb. The floor space is 20 × 22 ft.

Briefly, the bar is clamped tightly behind the heated end, and the plunger is forced against this end, forming it in the shape of

the die. More than one punch and die are required on most work. This is seen in Fig. 30 which shows also how this method economizes metal. Here the first set of dies merely upsets the end of the bar to the diameter and length shown. The second operation simply punches the center out of the enlarged end and leaves the sleeve or bushing the desired length and diameter. By using a bar of the same diameter as the hole desired in the bushing, there is no waste of metal.

A more complicated forging, and one that would be very difficult by any other method, is seen in Fig. 31. The flange in this case is $10\frac{1}{2}$ in. in diameter, the total length is $8\frac{7}{8}$ in., and

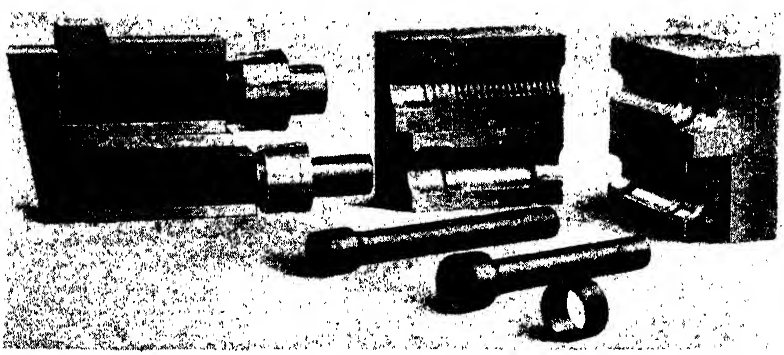


Fig. 30.—Typical dies for producing the ring at the right with no loss of metal.

the hole is $2\frac{1}{8}$ in. It is made in three blows at a single heat.

The bar is the size shown at *A* which is clamped in the dies at *B* with sufficient metal projecting to form end *C* and bulge *D* when punch *E* is forced against the hot end of the bar. As the end of the bar is upset, the sliding die *F* is forced toward the stationary die *B* and forms part *D*.

After this is done, the dies open, and the workman places the hot piece in the second die in which the flange *G* and the small projection in front of it are formed while *D* is shaped as at *H* by the punch and die seen at *I*.

Then the dies open again, and the work is moved to the third pair of dies where the punch *J* pierces the work and, with the assistance of the die at *K*, completely cuts the finished forging from the bar, as at *L*. The punch inside the work forces the metal away from the center so that it fills the die completely and produces a finished piece, as at *M*. Both parts of the dies are

shown, the half at the right showing the recesses in which the large flange is formed.

The bar is then ready for reheating and the production of another piece without any loss of metal. In the meantime, other

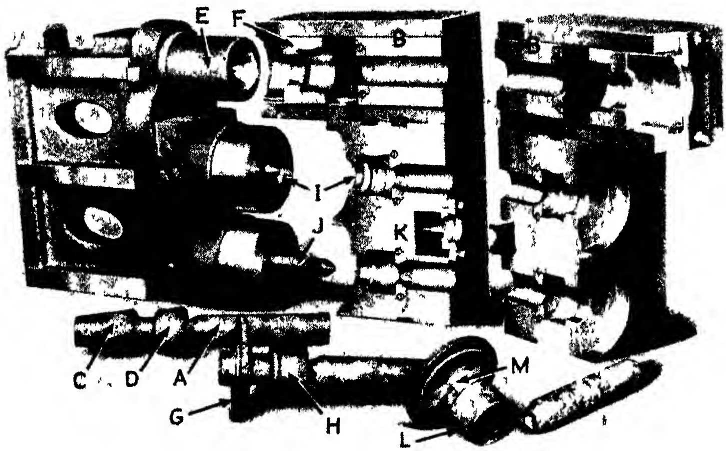


FIG 31.—Details of dies and operations to make the flanged piece shown at L and M. The scrap is seen at the right.

bars are being heated so that one is always ready and the forging machine need lose no time.

These illustrations were supplied by the National Machinery Co., Tiffin, Ohio.

CHAPTER VIII

GRINDING OPERATIONS

Grinding was originally a finishing operation, and although this is still true in many cases, grinding wheels and machines have been developed to the point where they are in direct competition with both planing and milling machines in the roughing of flat surfaces. Although the first developments of rough grinding were on cylindrical work and on crankshaft forgings for automobiles, grinding from the rough is now largely confined to flat surfaces. Some examples of this kind of work will be shown later in this chapter.

When used for finishing work, the grinding machine removes comparatively little metal. Its object is to correct irregularities due to machining or remove distortions caused by heat-treating. In either case, the metal removed is measured in thousandths of an inch as grinding is a process for correcting errors left by other methods.

Range of Operation.—The range covered by modern grinding runs from the grinding of fine threads in solid metal to the removal of unbelievable amounts of metal from large castings and forgings. The ability of the grinding wheel to maintain its shape in producing accurate threads is one of the achievements of the modern wheelmaker. On the other hand, the removal of large quantities of metal from castings and forgings, with the large, coarse-grained wheels, either solid or segmental, plays an equally important part in the economical machining of metal.

There is now a wide range of sizes in all types of grinding machines. Cylindrical grinders range from tiny ones used in finishing the shafts of watches and fine instruments to those capable of handling huge crankshafts and similar work. The largest yet built is for finishing field guns which are 65 ft. long. In between are numerous types, some of which will be illustrated. A similar range of sizes is to be found in machines for internal grinding, or the finishing of holes of various sizes; the same is

true of machines for producing flat surfaces by grinding. There are numerous machines for special work, such as the centerless grinding machine for both external and internal work.

Grinding has, in fact, largely relegated some of the other types of machines into the "roughing" class. In many classes of work, turning, boring, and milling or planing are considered roughing operations, the finishing being done by grinding, in some of its numerous forms, now including honing, lapping, and superfinishing, all of which are forms of abrasive finish.

As in so many instances, the selection of the best method of machining to be used in any given case calls for careful judgment, based on experience. Even without experience, it is well to be acquainted with the various methods available and thus prevent the selection of a poor method when obviously better methods are known. Even where grinding is to be used as the finishing operation, the preliminary machining should be done by the method that will leave the piece in the best condition for grinding. Although large amounts of metal can be removed by grinding, it is plain that best results are obtained by leaving only as much as can be removed economically by the grinder.

Several standard grinding operations are shown. Where the equipment is available, these are practices that can be safely followed. Following these are what may be called "emergency" operations because they were done without standard equipment or by modifying the machines and fixtures to suit the particular work in hand. In many cases these emergency methods have been remarkably successful in getting out rush work at high speed and low cost.

Grinding Wheels.—Great accuracy is required in machines for finish grinding. The spindle that carries the grinding wheel should run true and be firmly supported in its bearings. Except on small machines, plain or sleeve bearings have proved more satisfactory than either ball or roller bearings. Where very accurate work is required, it is customary to let the grinding machine run for from 10 to 20 min. before starting work. This is to let the bearings warm up to their running temperature so that even a small amount of expansion will not affect the accuracy of the work. It is also quite common practice to let grinding machines run during the lunch period so as not to require a warming-up time before work is started again.

Balance of the grinding wheels is also very important as, at the high speeds at which they are run, a slight unbalance will throw a wheel out of its true position and show on the work. When a grinding wheel has any appreciable amount removed from its face in sharpening, it is necessary to rebalance the wheel, as even slight differences in the density of the wheel in different spots might affect the work produced.

Sliding parts of grinding machines, whether they are for round or for flat work, must be kept true and have no lost motion, or it is impossible to secure really accurate work. Grinding wheels should receive good care both when they are in use and when stored between operations. It should be remembered that they are cutting tools with very small teeth and that they remove real chips the same as a milling cutter, only of much smaller size.

Wheelmakers have greatly improved the quality and uniformity of their wheels and can provide them suited to almost any shop condition. They should be consulted as to the best one for work of different kinds. With the new abrasives now available and the combinations that are made, it is possible to secure results that were unknown a few years ago. The wheelmaker's advice should be carefully followed both as to the kind of wheel and as to the speeds and feeds at which it should be used. Speed has a direct bearing on the performance of a wheel and can be varied to give different results. In no case should a grinding wheel be run faster than the speed given by the maker as being safe.

The speed at which the work revolves, in the case of cylindrical grinding, or the table travel where flat surfaces are being ground, affects the results obtained in grinding. Although no fixed rules can be given, it is safe to say that work speeds, the speed at which the work passes the grinding surface of the wheel, varies from 40 to 100 ft. per minute. For unbalanced work such as crankshafts or camshafts, where a very high finish is necessary, the speed for finishing may be as low as 15 ft. per minute, although from 30 to 45 may be used in many cases. On the other hand, such work as aluminum pistons may use a speed of from 100 to 200 ft. per minute.

Varying the speed affects the work in several ways. A slow work speed makes a soft wheel give similar results as one some-

what harder; a high work speed makes a hard wheel act as though it were soft.

The rate at which work passes the grinding wheel affects the finish and can give varying results. For rough grinding, the rate of traverse can be nearly as much as the width of the grinding wheel. This should be greatly reduced for a fine finish, usually not over 1/2 in. per wheel revolution. For very fine finishes, the work travel should be reduced to about 1/8 in. per revolution of the wheel. High work speed and slow traverse speed make possible a greater depth of cut.

Work speed is very important on work using formed wheels to produce a desired contour. Formed wheels have varying diameters and consequently run at different speeds. It is therefore necessary to consider the average diameter of the formed wheel and select the best speed for this diameter.

Grading of Grinding Wheels.—In order to simplify the selection of grinding wheels for the war effort the manufacturers have adopted a standard classification. The desirability of a uniform system for marking grinding wheels has long been recognized. On several occasions such systems have been given actual trials in selected groups of consumer plants. The last attempt showed promise. After a year's trial it was submitted and subsequently approved under American Standards Association procedure as an American Standard (B5.17—1943). Satisfactory reports from the limited number of plants in which it was tried proved premature, as in extending its use to other plants reactions were brought out indicating shortcomings.

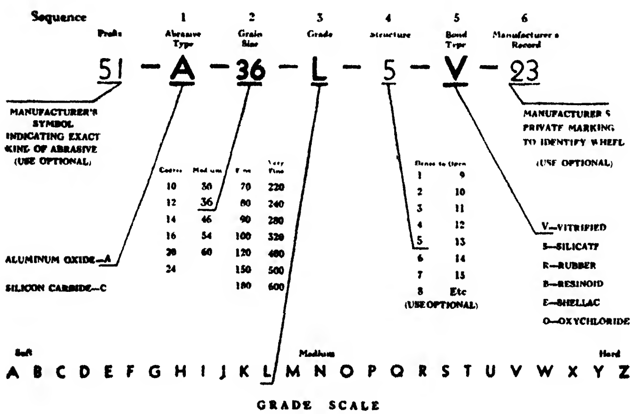
The committee of the Grinding Wheel Manufacturers Association is of the opinion that the principal reasons for the failure of the American Standard were that confusion existed because it was not made clear that wheels similarly marked, if made by different manufacturers, would not grind alike.

However, the grinding wheel manufacturers are agreed that much good can be accomplished by use of a uniform system of markings, provided the limitations of the system are clearly understood. The standard, submitted herewith, is a *standard of markings only* and not of grinding action. The most important revision was the adoption of an alphabetical marking system, for all bond types, to designate grade of hardness. Better provision was made for the wheel maker to incorporate into the marking

such special symbols as might be required to qualify properly the basic symbols of the standard markings.

Members of the Grinding Wheel Manufacturers Association have voted to adopt this system. The individual members will start putting it into effect as soon as expedient, but months may be required to make the transition complete. During this period and perhaps for a considerable time thereafter, wheels

STANDARD MARKING SYSTEM CHART



Adopted by Grinding Wheel Manufacturers Association in 1944.

may be marked with both the new standard and the wheel maker's own marking. This is referred to in the standard as "dual marking." It is intended that the Dual System will eventually be abandoned and that the new Standard Marking alone will be found to be adequate.

This was submitted to all grinding wheel consumers as a Grinding Wheel Manufacturers Association standard, March 16, 1944.

Purpose and Scope.—This standard applies to grinding wheels and other bonded abrasives: segments, bricks, sticks, hones, rubs, and other shapes, which are tools used to remove material, alter shape or size, produce a desired surface or accuracy of dimension, or a combination of these objectives.

The standard does not apply to diamond wheels or to specialties such as sharpening stones where radically different symbols are commonly used.

The Standard establishes a symbol for each of the most essential characteristics of a grinding wheel, and arranges these symbols in uniform sequence.

This is a standard *system of markings only.* Wheels bearing the same standard markings if made by different wheel manufacturers may not and probably will not produce the same grinding action. This desirable result cannot be accomplished because of the impossibility of correlating any measurable physical properties of bonded abrasive products in terms of their grinding action.

Sequence of Markings.—Each marking will consist of six parts, placed in the following sequence:

1. Abrasive type.
2. Grain size.
3. Grade.
4. Structure.
5. Bond type.
6. Manufacturer's record.

1. *Abrasive.*—Abrasives naturally fall into two distinct groups, namely the aluminum oxide group and the silicon carbide group. Letter symbols are used to identify these two groups, as follows:

A Aluminum oxide.
C Silicon carbide.

Where it is necessary to designate some particular type of these broad classes, the manufacturer may use his own symbol or brand designation as a prefix.

2. *Grain Size.*—Grain size is indicated by a number.

The following list (from coarse to fine) includes all of the ordinary grain sizes commonly used in the manufacture of grinding wheels.

10, 12, 14, 16, 20, 24, 30, 36, 46, 54,
60, 70, 80, 90, 100, 120, 150, 180, 220

The following additional sizes are occasionally used: 240, 280, 320, 400, 500, 600.

If and where it is necessary to indicate a special grain combination, the wheel maker may use an additional symbol appended to the regular grain symbol.

3. *Grade.*—The grade is indicated by a letter of the alphabet, A to Z, soft to hard, in all bonds or processes.

4. *Structure.*—The use of a structure symbol is optional. If and where it is advisable to indicate the structure in a wheel marking, a simple number symbol shall be used. Numbers from 1 to 15 will cover the range of structures being used today, but there is no reason why higher numbers cannot be used if necessary. Progressively higher numbers are used to indicate progressively wider grain spacing (sometimes called "more open" structure).

5. *Bond or Process.*—The bond or process is designated by the following letters:

V	Vitrified.
S	Silicate.
E	Shellac or elastic.
R	Rubber.
B	Resinoid (synthetic resins).
O	Oxychloride.

6. *Manufacturer's Record.*—Manufacturer's records are designated by symbols. Each grinding wheel manufacturer is at liberty to use the sixth position for private factory records.

Dual Marking.—Where the standard method of marking differs materially from the old form, it may be advisable to use both the old and the new markings during the introductory period, and perhaps for a considerable time thereafter. This would enable the user to become accustomed to the conversion gradually.

Where wheels are too small to permit the use of the complete marking, the grain and grade marking alone may be used on the wheel, or the marking on the wheel itself may be omitted entirely. Where this is done, the complete marking (including the dual marking where necessary) shall be indicated on tags or labels accompanying each container.

Wheel Manufacturer's Name.—Because of the greater similarity in marking that will result in many cases from the use of this system, it is important that the user include in his records the name of the wheel maker as a part of the marking.

Thread Grinding.—The grinding of screw threads on a commercial scale is a comparatively new development. Experi-

ments in thread grinding to correct distortion of taps after hardening were made in the toolroom of the Watervliet Arsenal over 30 years ago. Probably the first man to grind taps commercially from the solid was John Bath of Worcester who was an early exponent of grinding of various kinds. Since then, the practice has grown and is now found in many industries. It is not now confined to taps, but cylinder studs for aviation engines are ground from solid stock at speeds that would have been unbelievable a few years ago.

Standard thread-grinding machines are now available to handle almost any form of thread grinding needed in manufacturing. It has become such a common practice that ground threads are frequently specified on many classes of work and in many places where they are unnecessary. The use of ground threads is usually confined to fine pitches, especially where they are ground from the solid stock On threaded feed screws which are hardened to increase wear it is customary to finish by grinding after they have been hardened Practically all worm screws are hardened and ground where accuracy is required.

Threads can also be ground very satisfactorily in the engine lathe by the use of portable grinders of the tool-post type, such as the Dumore. Examples of this method will be seen in this chapter. Although the regular thread-grinding machines will of course produce work at a faster rate, the small shop can use this method very successfully and so handle work that would otherwise have to go elsewhere. The accuracy of the lead of the thread will of course depend on that of the screw on the lathe itself. In most cases the length of the thread is not enough to make a slight error in lead very important.

Grinding threads in the lathe requires more skill that is necessary in handling a standard make of thread grinder. For this reason, if for no other, the standard machine is best where it is necessary to train unskilled men or woman for this kind of work, as has been the case in much of the war work.

Much of the credit for the growth of thread grinding must go to the makers of grinding wheels that will maintain their accurate form. For when we consider the rather sharp angle of 60 deg. that must be maintained and the very narrow flat space that grinds the bottom of the thread, it is a great achievement to make a wheel that will stand up under these trying conditions.

A. Rosseau, a Norton Company engineer, advises the use of a vitrified wheel where the tolerances in either lead or angle are to be held within close limits. In this he includes such work as thread gages, taps, and lead screws. For high-production work, where extreme accuracy is not required, he suggests using the resinoid bonded wheels

In selecting the wheels to be used, the fineness of the pitch largely determines the grit to be used. This may vary from 220 grit for the finer threads up to 90 grit for coarser threads, using vitrified wheels. With the resinoid wheels the finest grit sug-

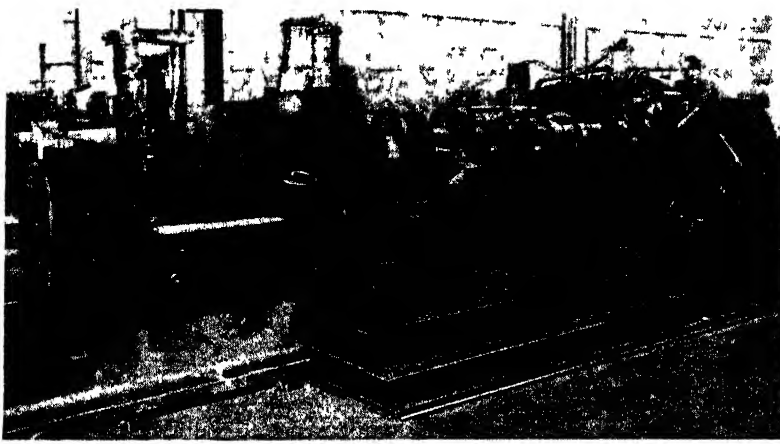


FIG 1—A large Landis crankshaft grinder that takes 216 in. between centers.

gested is 180. The best grit also depends on the material being ground. Hard steels grind best with a fine wheel. Lower speeds are also suggested for these steels, particularly when a fine finish is wanted. Finer and harder wheels are better for light feeds and high work speeds. Where the steel is tough rather than hard, slow speeds and heavy cuts, to reduce the number of passes, work out well. With this material, threads of 10 and 12 pitch are often ground in two passes. They have been ground at a single pass with a work speed as low as $1\frac{1}{2}$ to 2 ft. per minute. Finer threads, such as 18 pitch, are often ground at a single pass.

In thread grinding both vitrified and resinoid wheels are run at from 6,500 to 12,000 surface feet per minute, the high speed making a fine-grit wheel cut faster. They should never be run faster than the maker's recommendation.

Large Crankpin Grinder.—The huge Landis grinding machine shown in Fig. 1 swings 40 in. and takes 216 in. between centers. It weighs 114,000 lb., including the electrical equipment. By driving the shaft from both ends, the torque is minimized and better crankshafts can be produced. Both work heads can be moved along the bed to accommodate shafts of varying lengths, and special means are provided for balancing the shaft while it is

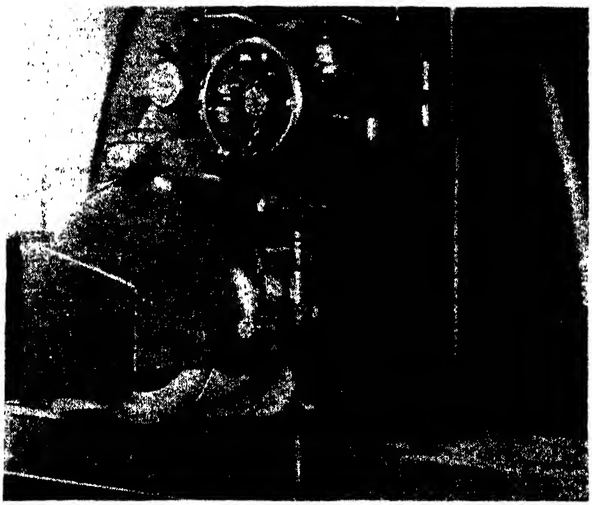


FIG. 2.—Grinding a string of breech blocks on a Mattison machine.

being ground. Provision is made for a variety of crank throws, and interchangeable clamping blocks make it easy to handle bearings of different diameters. An attachment for grinding the shoulders is also supplied. It will handle crankshafts up to 5,000 lb. in weight and requires a floor space 12 × 52 ft. The regular grinding wheel is 54 in. in diameter, and wheels up to 4-in. face can be used. The assembled grinding wheel head weighs 4,000 lb. Traverse speed can be varied from 4 to 100 in. per minute. The motors are 30 to 40 hp. for the wheel drive and 2 to 3 hp. for the work drive.

As shown, one of the crankpins near the operator is being ground. The work drive and the supports for the crankshaft permit adjustment so that each crankpin and each main bearing can be ground in turn. This requires careful balancing in each position.

Surface Grinding.—Views of the Mattison grinder reproduced herewith illustrate this machine operating on typical classes of work as handled in different plants. Some of these jobs are rather unusual for application of surface grinding methods and are therefore of especial interest as showing the flexibility of this line of machines for precision finishing of very heavy parts as well as work of considerably lesser proportions.

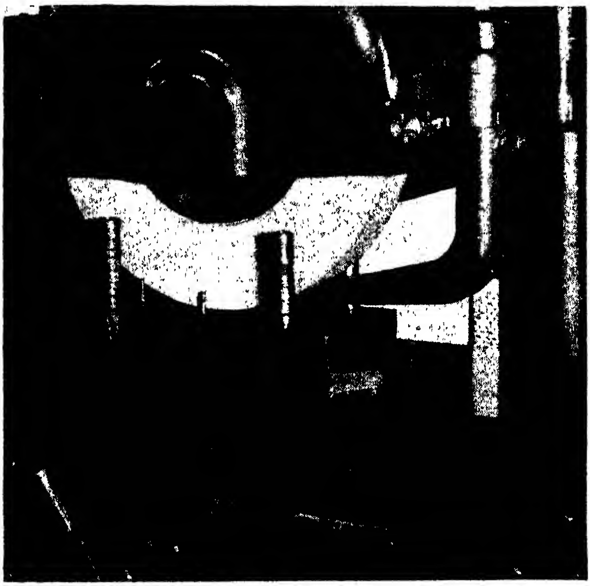


FIG. 3.—Resurfacing a punch-press die.

Figure 2 shows other heavy work, this view representing the precision grinding of a string of breech blocks for 3-in. antiaircraft guns. All four sides are ground and held to close tolerances. A long string of these blocks is loaded at one time on two magnetic chucks on this large-capacity grinder. Figure 3 shows the handling of dies with leader pins in place. Wheel and spindle clearance of these grinders, when equipped with oversize diameter wheels, is sufficient to cover this type of work easily. In addition to ability to remove stock rapidly, the advantage is presented of grinding dies assembled with leader pins, and time required for disassembly is eliminated.

As shown in Fig. 4, regular cast-iron, V-shaped, and flat ways can be ground. They eliminate scraping and, where way sur-

faces are hardened—as on the lathe bed shown—the grinder provides a method of obtaining an accurate and smooth finish A special wheel-truing device mounted on the wheel slide permits truing of both angles of the wheel for grinding V ways.

Grinding Small Holes.—As with many other operations, the selection of the machine and the method depends largely on the quantity to be ground and the skill of the available workers

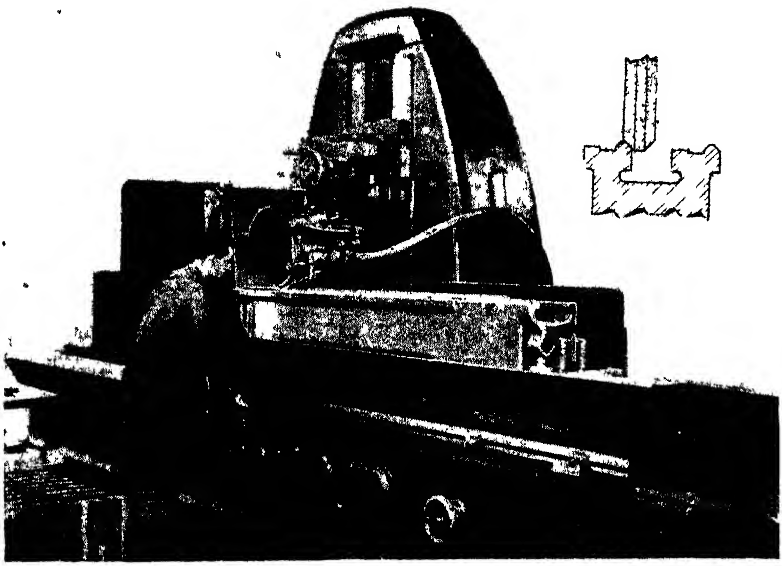


FIG. 4.—The grinding of lathe-bed ways The inset shows how the V's are finished

The automatic and semi-automatic machines handle work of this kind rapidly and accurately. But they cannot be used economically unless the production is large enough to warrant their cost. Then, too, they may not be available where and when wanted.

An example of small-hole grinding is seen in Fig. 5. This requires special, high-speed spindles which can run up to 30,000 r.p.m. if holes as small as $\frac{1}{8}$ in. are to be ground. A $\frac{1}{4}$-in. hole requires 20,000 r.p.m.; a $\frac{1}{2}$-in. hole requires 15,000 r.p.m.

Here is another place where a good tool-post grinder can be used to advantage. Or, one of the well-known internal-grinding heads can be mounted on the lathe carriage and excellent work produced in that way. It requires training to get workers to

handle the operation rapidly and accurately. But with proper stops to locate the cross slide of the lathe and a little training in using either plug, air, or indicating gages, semiskilled men and women can do a good job with this inexpensive equipment.

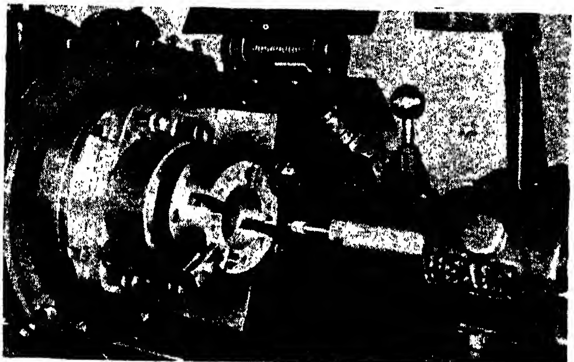


FIG. 5.—Small hole grinding on a Heald machine.

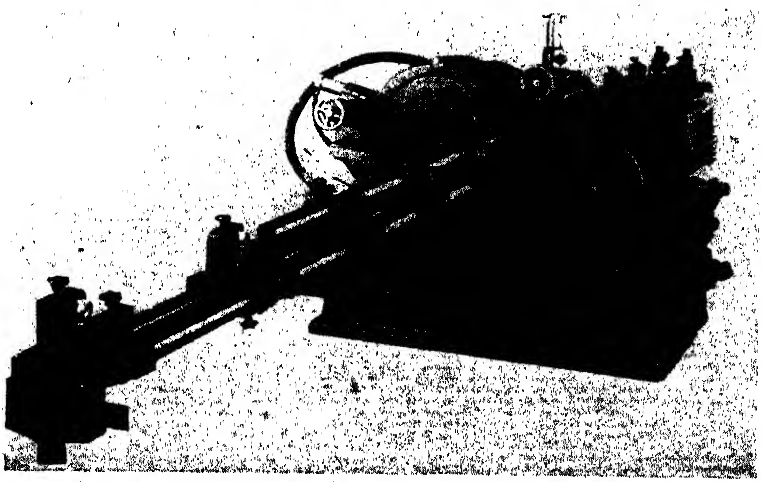


FIG. 6.—A centerless grinding machine for long bars.

Centerless Grinding.—Centerless grinding has made possible the adaptation of this process to many classes of work that could not otherwise have been machined in this way. On short work it makes possible the grinding of the entire length at one pass through the machine as it is unnecessary to have any driving dogs or to run the piece on centers. It is also used on long

shafts, as in Fig. 6, where the work is too long and slender to be held between centers.

This type of machine has been improved to enable it to produce work that is round and straight at much higher production rates

FIG. 7.—Grinding valves in a centerless machine.

than is possible with the older types. It will produce piston pins that are round, straight, and very accurate and also grinds pistons with a relief on each side. This is done by using cams that control the rotation of the piston and ensure just the

FIG. 8.—Internal centerless grinding.

desired relief on each side. Valve grinding is shown in Fig. 7. Centerless grinding is also applied to internal work as in Fig. 8. Here the work is rotated and guided by the outside diameter. The advice of those familiar with centerless grinding

work should be sought before the type of operation that is best suited to a job is decided upon.

Wet-belt Grinding.—Abrasive belts for grinding probably originated with John C. Blevney, in Newark, N.J., many years ago. Machines utilizing this application of abrasives are made by several well-known builders and should always be considered in planning shop operations to which they are fitted. They are comparatively inexpensive and are useful in many minor operations as well as in some that may be considered as major. In fact what may be minor operations in some shops are, of necessity, most important in others.

Wet-belt grinding is a late development of the Porter-Cable Co. in Syracuse, N.Y. It requires a belt special as to both bond and lap fastening. Such belts run up to 6,000 ft. per minute over flat plates which support the belt against work pressure. Cooling is secured by water or other liquids according to the work. On magnesium, mineral seal or kerosene can be used, but special oils are available that are free from objectionable odors. No dust-collecting system is necessary but, when used on magnesium, the chips should be cleaned out before other materials are ground.

Grinding Big Piston Rings.—Maintenance jobs of all kinds are important in keeping equipment operating properly. This applies to all industries. Ships' machinery, engines, and auxiliary apparatus are no exception.

Figure 9 shows how a big piston ring for a diesel marine engine was surface-ground on a Norton 10 × 36 in. hydraulic surface grinder where the work was held flat on the magnetic chuck. The rings were 29 in. in diameter. They were first rough-ground on the sides to within 0.0005 in., then reset on the chuck, and reground to exact thickness, no variation in thickness being found upon application of micrometers at different points around the circumference. This is a severe test of the accuracy of the machine, the magnetic chuck, and the wheel.

The rings had to be placed in three different positions in covering the entire surface with the wheel. Yet no variation in thickness could be found in spite of the fact that, after finishing the face for one-third of the distance around the ring, it had to be turned on the chuck to permit another third to be ground, and so on. This was in the General Engineering & Dry Dock Co. shop in San Francisco, Calif.

Railroad Maintenance Grinding.—Grinding machines are being used more and more in repair work of various kinds. Progressive railroad shopmen find them extremely useful in such work as piston and valve rods, crankpins, and valve motion parts. Internal grinders are also used in repair work on air-brake and other cylinders, rod bushings, rod ends, and smaller work such as triple valve parts.

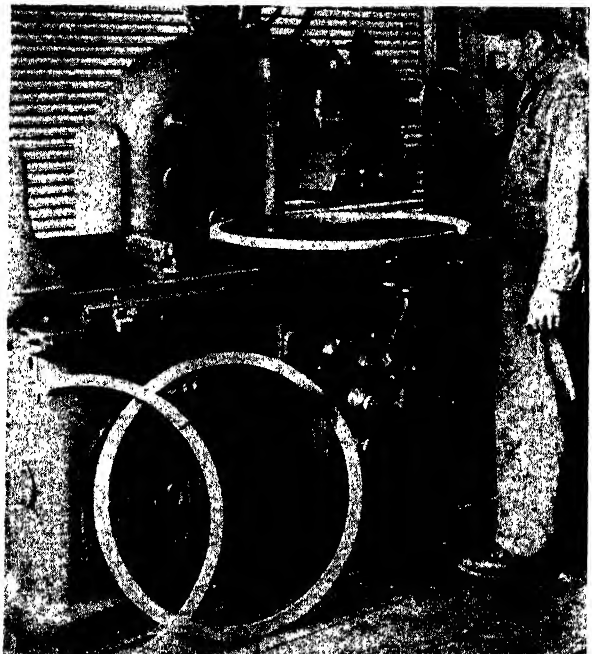


FIG. 9.—Piston-ring grinding on a Norton machine.

Figure 10 from a Southern Pacific shop shows a piston rod being ground in a gap bed machine which makes it unnecessary to remove the piston from the rod. As the rod wears, it is ground down just enough to remove the worn spots. In most cases a ¼-in. reduction is permissible for rod diameter. When the grinder is used, it is possible to true up the rod with less reduction in diameter than by turning.

Large internal grinding, such as reconditioning air-brake cylinders and grinding the ends of connecting rods for the floating bushings, is done on the planetary type of machine as seen in

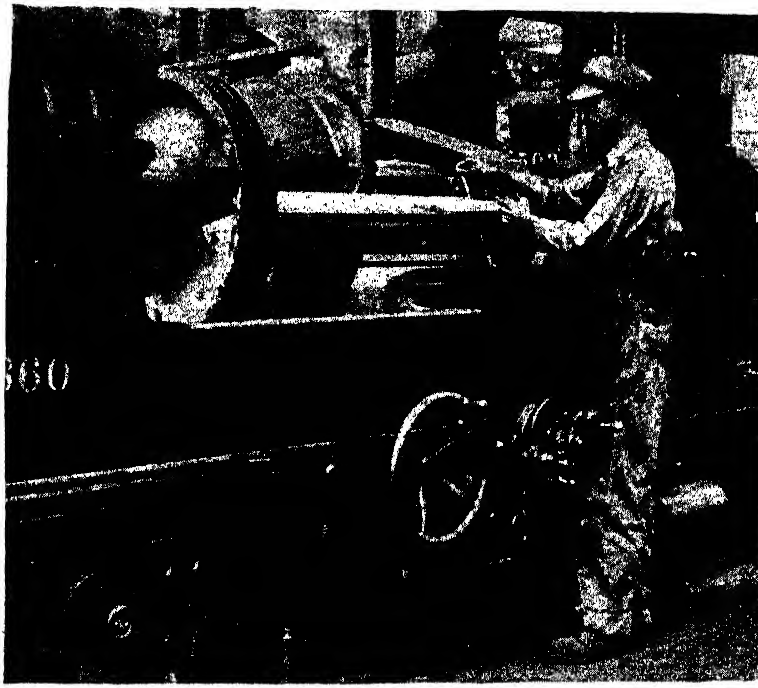


FIG. 10.—Regrinding a locomotive piston rod with the piston in place.

FIG. 11.—Grinding the bore of an air-brake cylinder with a planetary machine.

Fig. 11. Here the grinding spindle is held in an eccentric sleeve which can be adjusted to carry the grinding wheel around the inside of the cylinder to be ground. A large machine built particularly for railroad work is shown carrying a large grinding wheel. In this case the work remains stationary, and the wheel travels around in contact with the cylinder bore while it is being driven at its usual speed of approximately 6,000 surface feet per minute.

The cylinder is supported at the large end by the lugs at the side and is centered by the ring in front. Part of this centering

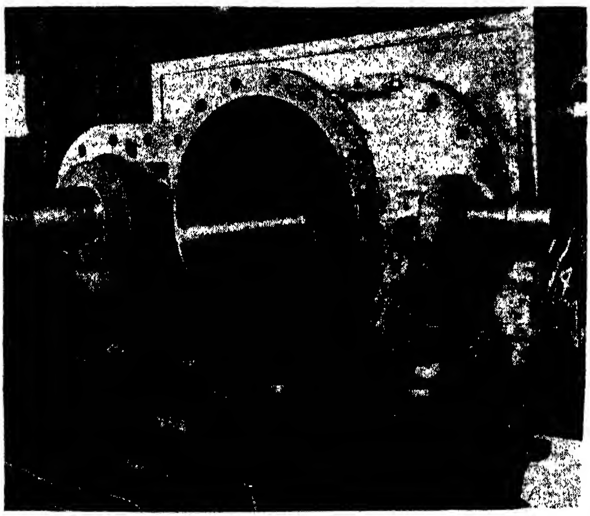


FIG. 12.—Another cylinder grinding job.

ring is swung up out of the way. Bolt holes in the cylinder flange are used in centering the bore of the cylinder. An indicating device in the tailstock of the grinder aids in securing correct alignment.

Planetary Grinder in the Railroad and Repair Shop.—Before the introduction of honing as a method of finishing automobile cylinders, the planetary grinder was considered a production machine. Nearly all shops building automobile engines had batteries of these grinders for finishing the cylinder bores. Now this type of grinder is usually found only in railroad and other repair shops, where it is a most useful machine. The name "planetary" comes from the design by which the grinding wheel

is made to travel around the cylinder bore while at the same time the grinding wheel revolves at its usual speed of 6,000 surface feet per minute. The radius of the path in which the wheel travels is of course adjusted to suit the work to be ground.

The wheel spindle of one of these grinders is shown in Fig. 12, with the wheel about to enter the small bore of a locomotive air-brake pump. In this case the wheel is nearly as large as the

FIG. 13.—Grinding a conveyer worm in a lathe.

bore it is to grind. The same wheel has been used in grinding the large bore at the right, the path of the wheel having been adjusted to the proper radius for the work.

This same method is used in grinding the ends of connecting rods to receive the floating bushings that run between the rod and the crankpin in the driving wheel. These machines have many fields of usefulness in a large variety of work.

Grinding Steel Worm Threads.—Steel worms used by the El Dorado Oil Works, Oakland, Calif., are for feeding copra and other vegetable oil materials through the processing machines. These worms are approximately 6 in. in diameter made with a coarse-pitch helix for the material being fed through the grind-

ing mill. The worm sections are short cast-steel members with ends ground also to allow them to abut properly in line when assembled on a long spindle or shaft where they are drawn snugly together by a heavy nut on the shaft end.

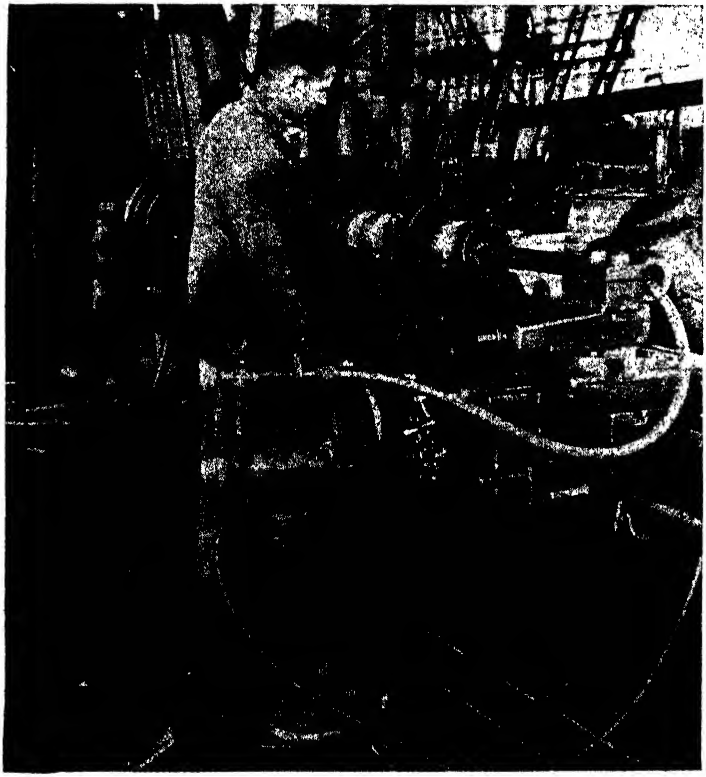


Fig. 14.—Grinding a taper hole with a wheel driven by a flexible shaft.

This assembled unit revolves like a conveyer screw in a long cylinder with minimum clearance. The worm must run quite true from end to end to avoid interference with the interior of the barrel or cylinder in feeding the materials to the mill. There is a severe abrading effect produced by the materials handled on the worms, to offset which they are heavily faced with Stoodite. Grinding of the worm after hard facing is done in a homemade machine (Fig. 13). This has a swivel adjustment for the wheel spindle to set it in an angle in the vertical plane to conform to the worm being ground. The wheel spindle is driven by a motor

on the rear bracket, by V belts. The worm is rotated slowly by reduction drive from a motor on the head of the machine, and also moved past the wheel at the proper rate. The ends and other parts are ground square to the center line on a Norton hydraulic grinder.

Grinding a Taper Hole with a Flexible-shaft Machine.—The views in Figs. 14 and 15 show the use of a Haskins portable machine in the grinding of long taper holes in Corrosiron nozzle tips. The holes to be ground were on a taper 18 in. long with the large end 6.158 in. in diameter. The small end, 3.640 in., had to

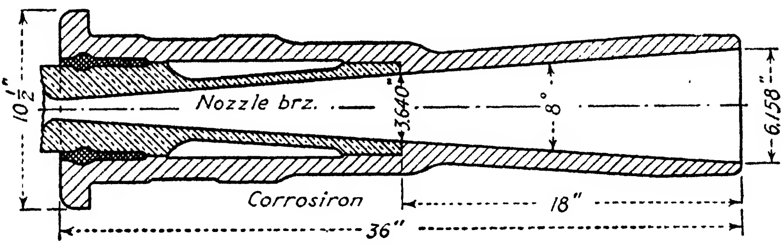


FIG. 15.—Details of the Corrosiron nozzle.

meet exactly the large end of a tapered hole in an inserted bushing of bronze which fitted a straight ground hole in the casting and extended the remainder of the nozzle length, or a distance of 18 in. also. This grinding job was really of the precision class for the taper had to be continuous throughout the total of 36 in. of nozzle length.

The alloy casting was 250 to 300 Brinell and 50 Scleroscope hardness. The taper figures were cut at 8 deg. or 0.139 in. per inch of length. For grinding, the wheel spindle was fitted in the outer end of the quill or holder, and the flexible shaft was slipped into the hollow holder and engaged the drive end of the wheel spindle. The portable machine was placed suitably near the lathe to allow the wheel to traverse the length of the work with the flexible shaft always in operative position. The work was ground first on its outer surface to provide two true spots for steady-rest use and was set up in the lathe to run true with the outer end carried in the steady rest.

The lathe taper attachment was set at 4 deg. taper, and the carriage was fed in the usual manner to carry the wheel through the 18 in. length of taper bore.

Portable Grinder on the Lathe.—The portable grinder, shown in Fig. 16, is helping out the grinding department in an application where the job is carried out on a South Bend lathe with the grinder on the compound rest of the lathe where all adjustments are readily made to position the wheel in relation to the work and for adjustment to different depths of cut. The method of chucking the job is shown, three jaws grasping the interior of the

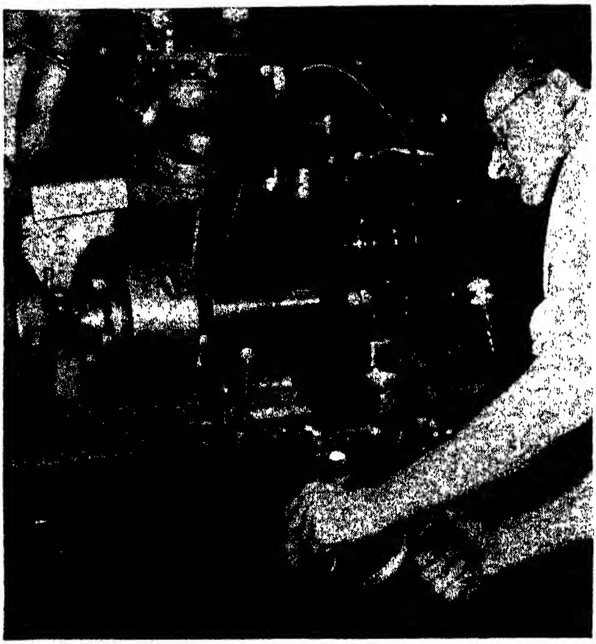


FIG. 16.—Using a portable grinder on an engine lathe.

shell-like piece. In work of this kind, a good portable grinder is a wise investment. It is not a production machine, but for many places it saves much time and money.

Grinding Taps from the Solid with Portable Grinder.—A number of taps had to be made, 1½ in. in diameter by 18 threads, U.S. form (or American) special fine threads. These taps were ground from the solid after fluting and hardening the blanks. The threads were ground in a Pratt and Whitney 16-in. Model B lathe with a Dumore grinder. The work was done by the Connor Mfg. Co., San Francisco.

FIG. 17.—Using a portable grinder to grind taps from the solid

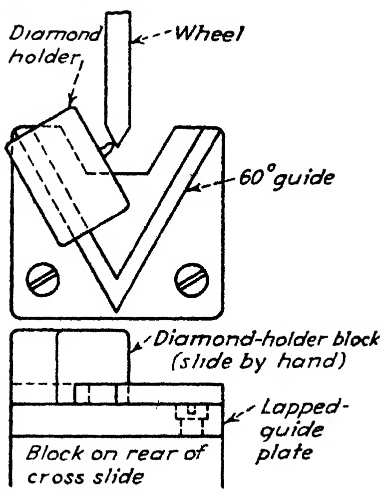


FIG. 18.—Fixture for dressing the grinding wheel with a diamond

The blanks were turned to a diameter of 1.52 in., leaving a full 0.012 in. for sizing by grinding on the tap portion proper. They were then fluted; the shanks squared; and the taps heat-treated. Then the bodies were ground to size, and the taps were ready for the grinding of the thread.

The grinder was mounted on the compound rest of the lathe as shown in Fig. 17. The grinder was adjusted with the wheel spindle tilted to bring the path of the wheel periphery into line

FIG. 19.—Backing-off the end of a tap with concentric relief.

with the helix of the desired thread. This helix angle figured out at 41 min. to which the wheel spindle was tilted.

A 6-in. wheel was used down to 5 in. before changing to another wheel. The wheel, a National No. B-2-70, was run at 8,000 ft. per minute, surface speed. The taps were made of Rex Double A, high-speed steel.

The wheel was dressed, after roughing, at each pass along the thread. The fixture for dressing is illustrated in Fig. 18. It has a T-shaped base attached to the rear of the tool slide on the lathe carriage, with a top plate having a true scraped surface on which is a 60-deg. lapped guide, exactly square with the axial line of the lathe centers. The diamond is set in a block of steel

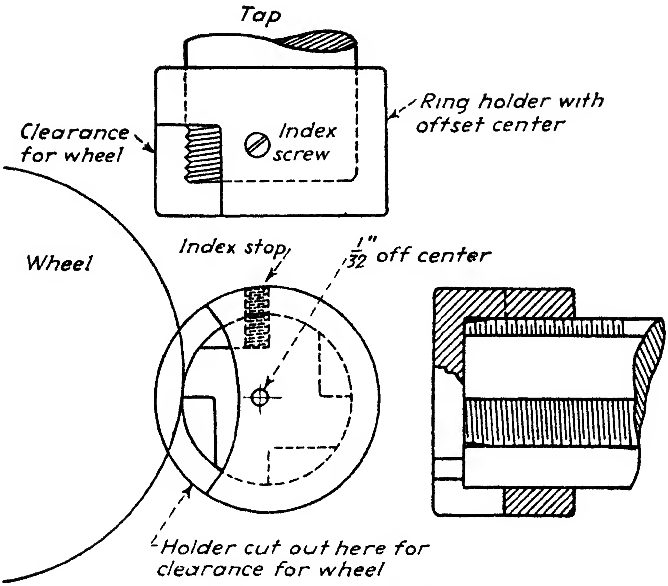


FIG. 20 — Fixture used in backing-off the end of a tap

FIG. 21 —Using two Dumore portable grinding heads, external and internal on one machine.

with a shoulder on the lower face fitting against the V guide on the fixture. The dressing consists in sliding the block along each side of the V guide to dress each side of the wheel.

Then the taps were ground on the ends for relief or eccentric backing off at the starting point, as in Fig. 19.

Eccentric relief was obtained by a dummy center on the tap, a ring with one side milled out to give an opening over one tap

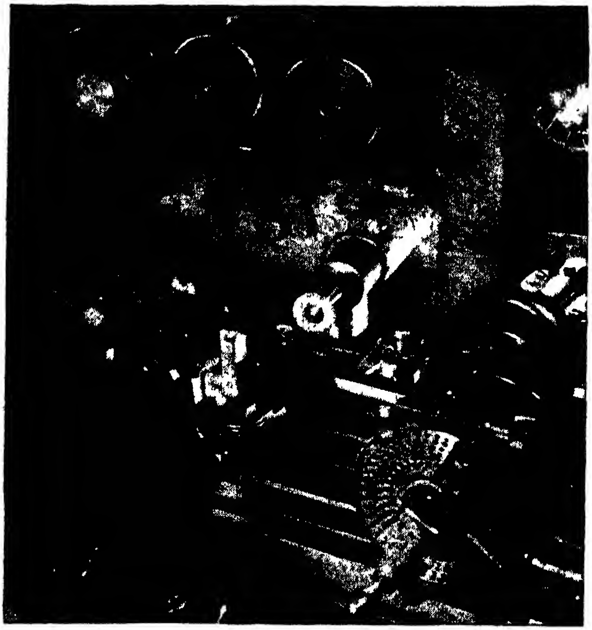


FIG. 22.—A similar portable grinder on the overarms of a milling machine.

land at a time, to permit the wheel to engage that land. The dummy is offset $\frac{1}{32}$ in. and placed over the tap to allow it to be rocked by hand in an eccentric path for the backing-off operation. This ring has a setscrew for locating and indexing the tap by contacting the bottom of the flutes. This is shown in Fig. 20.

Other Applications.—Other applications of the portable grinder to general machine-shop use are shown in Figs. 21 and 22. In Fig. 21 the table and driving head of a Greenfield tool grinder make a base for using two Dumore portables, a No. 5 for internal work and a No. 12 for external grinding. Such a combination makes a very useful machine. The job shown required a concentricity of 0.0005 in.

Figure 22 shows another portable of the same make, attached to the overarms of a Kearney and Trecker milling machine and used in grinding hobs. As in all grinding operations, care should be taken to protect the ways of the machine from abrasive particles.

An unusual application is seen in Fig. 23 where the grinder is mounted on the back of a lathe carriage with its spindle at right

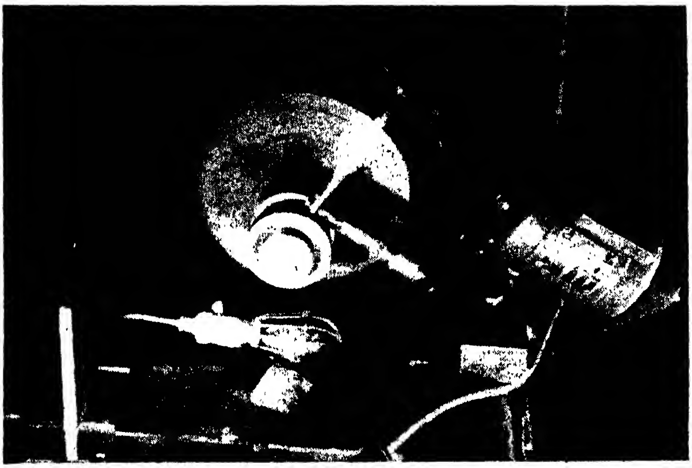


FIG. 23.—Portable grinder mounted at right angles to a lathe.

angles to the lathe. The work is one of a series of hardened steel rolls. As these are for rolling tubing that must be held to close dimensions; the grinding wheels must be kept to size. It will be noted that the grinder is mounted on the compound rest of the lathe which has been run to the back side of the lathe and turned at right angles to the saddle. This may offer suggestions for other unusual applications of portable grinders.

Grinders in Heavy Production Work.—Although grinding was formerly a finishing operation, it is now used in removing large amounts of metal in competition with planers and milling machines. Most of this competition comes in the surface grinding of work of various kinds on machines of various types. The following illustrations show the work of the Blanchard grinder. This machine was illustrated in an earlier chapter among the different types of machines used in shopwork.

The first example (Fig. 24) shows cast-iron bearing caps which present a surface $11\frac{1}{2} \times 12\frac{1}{4}$ in. from which about $\frac{1}{4}$ in. of

FIG. 24.—A Blanchard grinder grinding surfaces of cast-iron bearing caps.

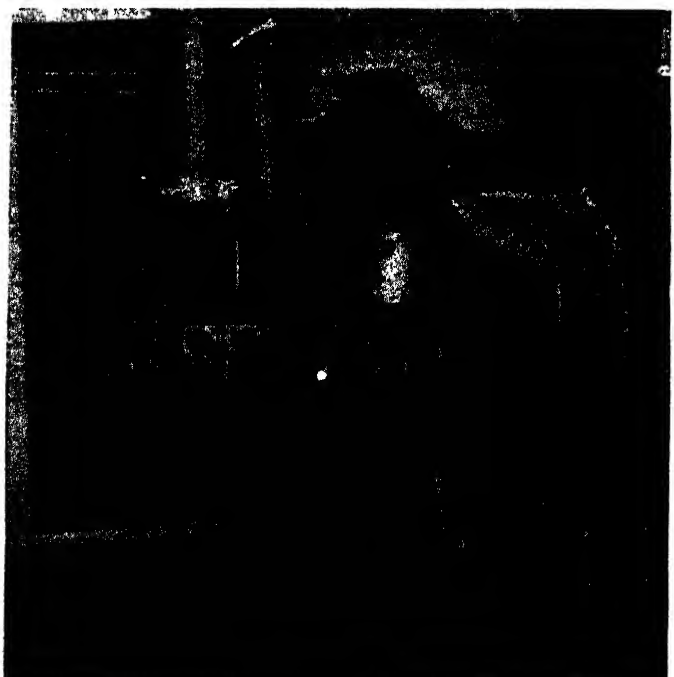


FIG. 25.—The surfacing of oil-burner pump bodies to close tolerances.

stock is removed by the grinding wheel. The bearing rests on parallels and is surrounded by other pieces of steel, the whole being held in place on the rotating table by the magnetic chuck, so that no clamping bolts are necessary. This grinds seven pieces per hour to a tolerance of 0.010 in.

Another cast-iron job is shown in Fig. 25 where oil-burner pump bodies are both roughed and finished on the same machine.

FIG. 26.—Surfacing a base plate 33 × 57 in.

Between the two operations the bodies are normalized by heating. The other machining operations are done before the finish grinding. The magnetic chuck holds 12 pieces at each setting, the bodies being 6 in. in diameter. The stock removal is only 0.012 in., but the tolerance is minus 0.0001 and plus 0.0003 in. The machine handles 48 pieces per hour.

Large work can also be handled in the same way. Figure 26 shows a large base plate 33 × 57 in. Here 3/16 in. is removed from each surface to a tolerance of plus or minus 0.005 in. and a flatness within 0.0015 in. These give some idea of the advances that have been made in grinding practice due to both improved machines and better grinding wheels.

In contrast with this work, Fig. 27 shows optical flats being ground on the same type of machine. The flats are held in a mastic-covered plate which holds 37 pieces, 35 mm. in diameter. The wheel removes 1.5 mm. in 2 min. For finishing for the final polish, a 400-grit diamond wheel is used.

A huge magnetic chuck is shown in Fig 27*a* It is about 12 ft long and vertical The work is part of a steel propeller blade

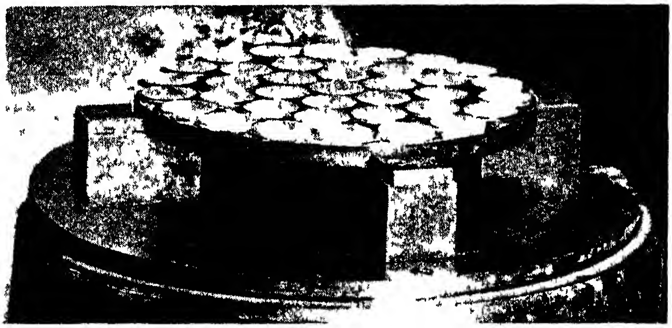


Fig. 27.—Grinding optical flats held on a mastic-covered plate

Fig. 27*a*.—A 12-foot magnetic chuck used in steel propeller blade work.

Holding Nonmagnetic Material on a Magnetic Chuck.—Magnetic chucks are so convenient and save so much time in grinding iron and steel parts that several ways have been devised for holding nonmagnetic materials on them. As these chucks

will hold only magnetic materials, it is necessary to devise means by which iron or steel parts can be made to hold nonmagnetic materials against the impact or cutting stresses put on the work by the grinding wheels. This means that the work must be held by devising pieces of iron or steel that will fit around the nonmagnetic material and take the stress of the grinding wheel.

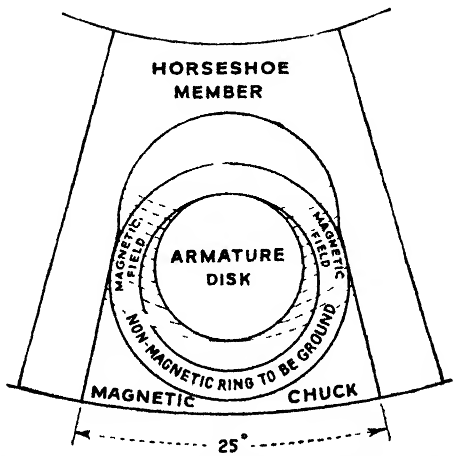


FIG. 28.—Holding a nonmagnetic ring on a magnetic chuck for grinding.

A simple application of this is shown in Fig. 28, where a ring of nonmagnetic material is anchored between the poles of what is virtually a horseshoe magnet with another magnetic piece inside the ring. As may be seen, the inner piece holds the ring to be ground firmly against the sides of the V opening in the outer piece. As this was done on a Blanchard grinder, the sides of the outside piece were made at such an angle that a number of them could be placed around the table and so ground at one setting. Twelve could be set up at the same time.

With the 25-deg. opening shown and the armature disk in the center, the magnetic lines tend to draw the inner block toward the center and so help to hold the ring of nonmagnetic material firmly in place.

Other similar applications of this same principle are seen in Fig. 29. Steel blocks inside the ring help position the bronze ring but do not prevent its turning. A rod in the hole drilled through the ring is clamped by the piece resembling a Z bar. The inner end of the pin contacts the end of one of the inner

blocks, and the long end of the Z bar is attracted by the magnet in the chuck.

In the third case (Fig. 30), the brass ring is held by the magnetic blocks around the outside bearing on the thin flange next to the table. As may be seen in both the Z bar and these wedges,

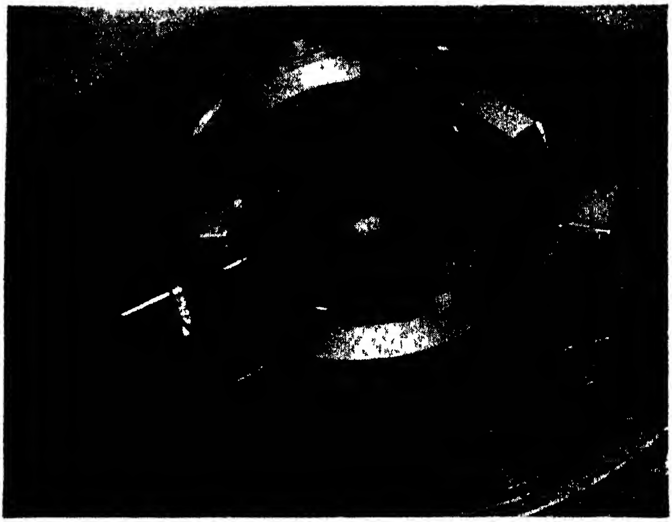


FIG. 29.— Another wav of holding nonmagnetic material

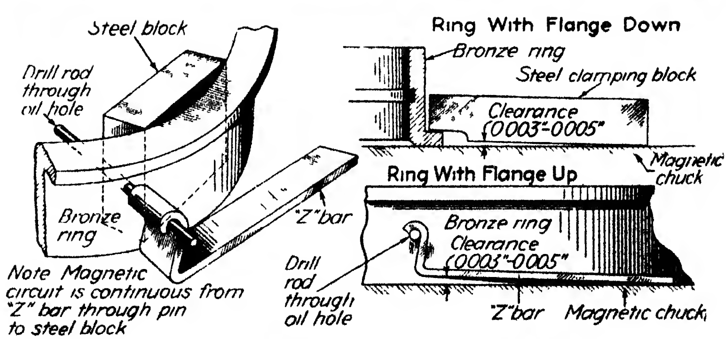


FIG. 30.—Details of method used in Fig. 29.

a slight air gap is left to ensure that the pull of the magnetic chuck holds the work firmly in place.

Grinding Thin Brass Pieces.—To hold thin pieces of steel on a magnetic chuck is very difficult when the work is of brass and the thickness of the work does not permit the use of steel

pieces beside it, as is the case with thicker pieces of work. The alternative is to use some kind of wax or other holding agent to *surround* the work—not to be under it on account of the inability to keep it level.

One method that has been used successfully is shown in Fig. 31. Here the work is held firmly on the plate while the melted wax is poured around, it as shown. The steel plate can then be held on the magnetic chuck. Unless care is taken, the heat generated by the grinding operation will melt the wax and loosen the work.

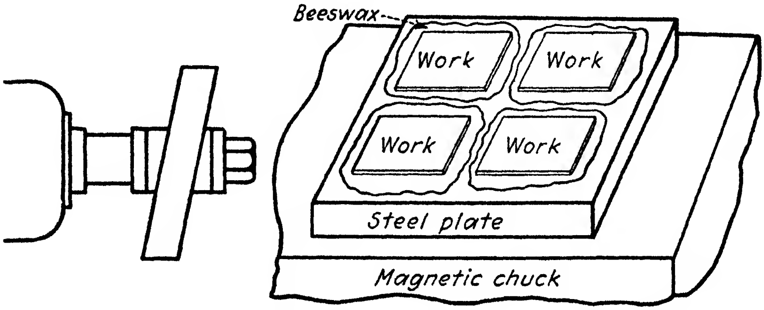


FIG. 31.—Holding work with wax.

To avoid this, it is suggested that the grinding wheel be mounted as shown and the face of the wheel trued after being mounted in this way. It may not be necessary to mount it at quite such an angle, but the reason for so doing is to avoid constant contact between the wheel and the work and so avoid heating the work enough to soften the wax.

The intermittent cutting and fanning action of the wheel is said to keep the work cool enough to permit the wax to hold it during the necessary grinding time, using of course, a very light grinding chip. This was suggested by Ira S. Williams.

Honing.—Honing, another form of grinding because it is done with the use of abrasives, is a finishing operation and very closely allied to lapping. It is, in fact, difficult to make a very satisfactory distinction between the two processes. They differ from grinding in that in either process the abrasive member fills the hole completely; in grinding the wheel is smaller than the hole and makes contact with one portion of the work only. This refers only to internal honing, which covers all but a small proportion of the work done by this method.

Honing is done with a combination of rotating and reciprocating motions. In most honing machines both motions are imparted to the hone while the work remains stationary. If it is easier to rotate the hone and move the work back and forth over it, it is done in that way. By this combination, honing can be

Fig. 32.—A Bryant handling device for airplane cylinders.

done in a lathe, revolving the work or the hone and moving the other back and forth over it with the carriage.

In an emergency the carriage can be moved by hand while the hone or the work is revolved at the proper speed. If there are too many parts to be done by hand but not enough to warrant buying a regular honing machine, an old lathe can be rigged up to move the carriage back and forth by power. This can be done either from the lathe headstock or by using a separate motor. The right-angle motion reciprocating can be secured by bevel gearing and suitable crank connections to the carriage.

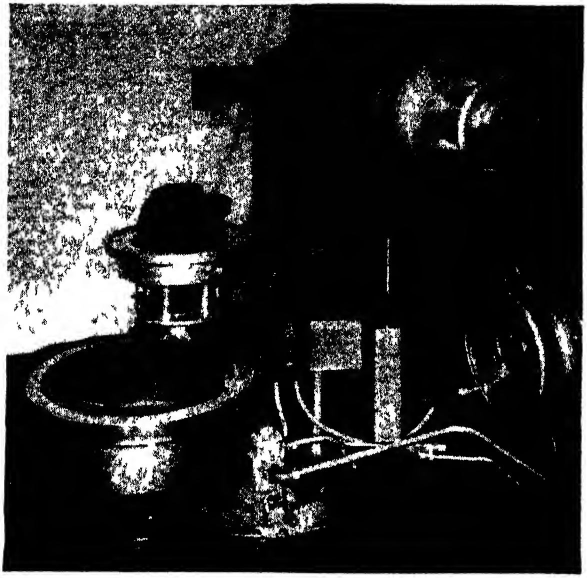


FIG. 33.—A cylinder in the carrier ready to be placed in the grinder.

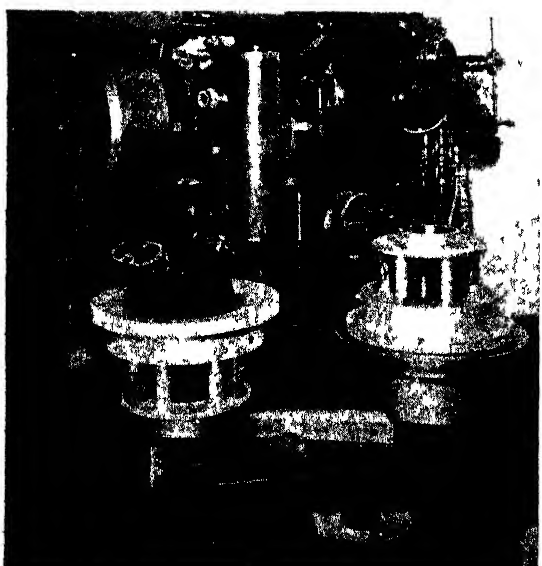


FIG. 34.—Lifting arm ready to raise cylinder and carrier.

By introducing more than the two constant motions, such as varying the length of the strokes so as to avoid a regular pattern in the path of the abrasives, we have what is known as superfinish. This was developed by David Wallace of the Chrysler Corp. and has been carried to great perfection in obtaining almost perfect surfaces. Some of these reduce the surface imperfections to one or two millionths of an inch.

Lapping.—Lapping is also an abrasive process. Instead of using an abrasive wheel or stone, the abrasive used is in powder form and worked into, or embedded in, metal or other material. Lead, copper, and cast iron are frequently used to hold the powdered abrasive. Hardwood or plastics can also be used.

Lapping is used on both cylindrical and flat surfaces: In the latter case the lap is usually a cast-iron plate, planed and finished as nearly flat as practicable and "charged" by rolling the abrasive into the surface. The surface of the lap is frequently checkered by shallow grooves planed at right angles across the face.

Lapping of this kind is used only to remove very small amounts of metal to make a surface as flat as possible and secure accurate contacts of mating parts. It is also used on the surfaces of standard gage blocks and for similar parts. This can be done either by hand or by power.

Round surfaces are also lapped either by hand or by machine. With either holes or cylinders, such as ring or plug gages, or piston pins, the lap is reciprocated while the work revolves. In this work lapping resembles honing so closely that it may not be easy to distinguish between them or to choose between them. Honing has largely replaced lapping in most manufacturing as it is usually a much more rapid process and consequently less expensive.

Handling Work at the Grinder.—Methods of handling work in and out of the machine are often as important as the operation itself, especially when the work is heavy. To get the most out of rapid machining operations, it should be possible to handle work easily and quickly between operations. An interesting case of this kind is shown in Figs. 32 to 37 which show a development by the Bryant Chucking Grinding Machine Co. to facilitate handling aircraft engine cylinders in and out of their machine.

The finish grinding of these cylinders is done after the aluminum head has been shrunk on so as to correct any distortion

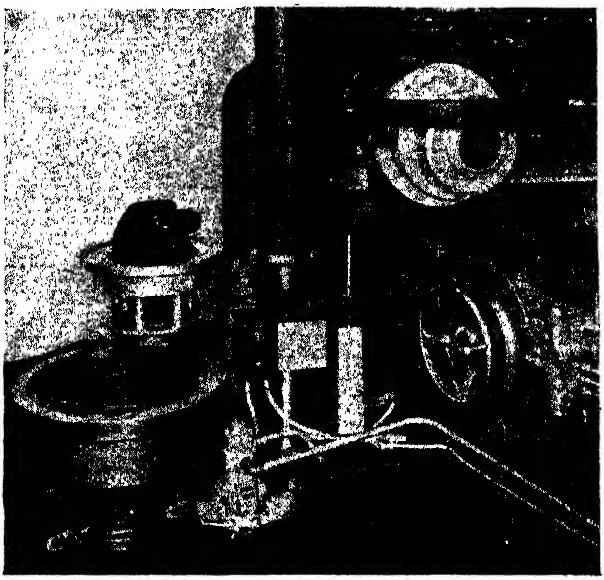


FIG. 35.—Carrier and cylinder are in place on the grinder. The lifting-arm is swung free ready to return.

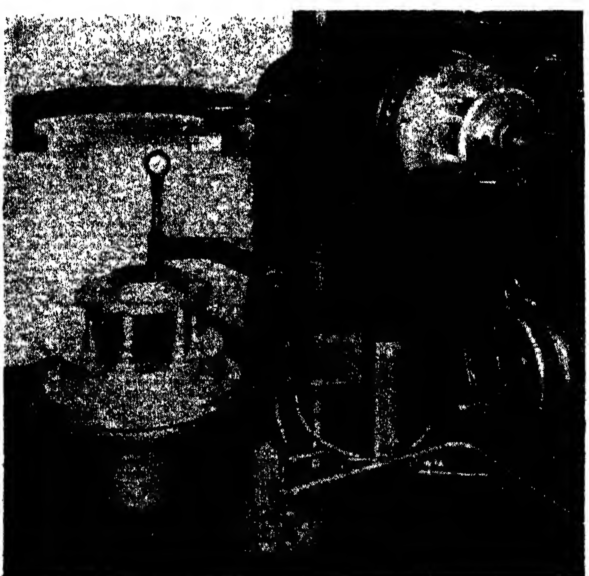


FIG. 36.—Carrier returned. The finished cylinder bore is being checked for size.

that may have taken place. The handling device is shown in Fig. 32, bolted to the grinding machine and providing a method of quick and accurate handling. The cylinder shown on the floor at the left is placed in the cage nearest it. The power hoist with the half-circle arm is lowered and swings under the flange of the cage that holds the cylinder. Both are then lifted by power and swung over to the other holder, seen in the foreground of Fig. 33, being turned over before it is lowered into this holder, as in Fig. 34, which shows a cylinder in each holder.

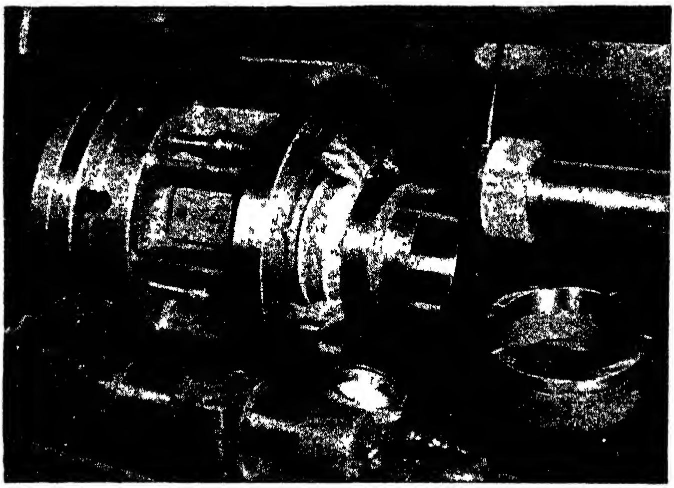


FIG. 37.—Another type of carrier used for grinding cylinders.

In Fig. 35 the cylinder has been lifted from the front holder and placed in the grinding machine chuck, which is shown in more detail in Fig. 37. The holder is shown in the chuck in Fig. 36. The arm is swung back out of the way after having lowered a cylinder that was ground previously into the stationary holder where the bore is being finally checked with a dial gage.

Although the chuck shown in Fig. 37 is for a water-cooled cylinder, the principles of the clamping methods used are similar and show the care used to secure extreme accuracy in work of this kind. It may be noticed also that there are two foot controls for the power lifting device, one at each side of the base. These make it easy for the operator to handle the hoisting mechanism and still have full use of both hands for guiding and fastening the work in the chuck.

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